A Dissertation on

ASSESSMENT OF NORMAL CEREBRAL SULCAL DEVELOPMENT IN FOETUS USING MRI

submitted to

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY
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CERTIFICATE BY THE INSTITUTION

This is to certify that **Dr.T.RAJAKUMARI ,** Post Graduate Student [May2015 to May 2018] in the Department of Radiodiagnosis, Government Stanley Medical College, Chennai- 600 001, has done this dissertation entitled **"Assessment of normal cerebral sulcal development in foetus using MRI"**under my guidance and supervision in partial fulfillment of the regulations laid down by The Tamil Nadu Dr. M. G. R. Medical University, Chennai, for M.D. [Radiodiagnosis] Degree Examination to be held in May 2018.

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DECLARATION

I, **Dr.T.RAJAKUMARI ,** declare that I have carried out this work entitled **"Assessment of normal cerebral sulcal development in foetus using MRI"**under the guidance of Prof. Dr.G.Sathyan in the Department of Radiodiagnosis, Government Stanley Medical college and Hospital. I also declare that this bonafide work or a part of this work was not submitted by me or any other for any award, degree, or diploma to any other university or board either in India or abroad.

This work is submitted to The Tamil Nadu Dr. M. G. R. Medical University, Chennai in partial fulfilment of the rules and regulation for the M.D. [RadioDiagnosis] Degree Examination.

Dr.T.RAJAKUMARI .

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I.INTRODUCTION

I.INTRODUCTION

The intrauterine cerebral cortical development can be divided in to three stages – neuronal cell proliferation and differentiation from its precursor cells , neuronal migration and complex cortical organization. Neuronal migration is the process of migration of differentiated neuronal cells from the peri ventricular germinal matrix zone to the pial surface following a radial pathway taking place between 7 th to 20 th week of gestation(1),whereas Sulcation /gyration is a phenomenon that is not much a temporally related to migration process (2). Sulcation is a sequential process of disproportionate rapid development of outer cortical surface than the inner white matter so that the cortex ends up in up in wrapping around and folding over itself ,hence forming cerebral sulci and respective gyri (3).These sulci and gyri become more evident during the course of foetal development and they constantly occupy relatively same locations ,which itself act as a precise reference(4) .The timing of the appearance of these different types of sulci is so precise that neuropathologists consider gyration to be one of the reliable estimate of gestational age and consequently good marker of brain maturation (5).

Although abnormalities of cortical formation and migration anomalies are felt to be rare ,they are indeed seen in more than 20% of CNS anomalies identified on postnatal MRI (6).They may be either isolated or associated with some other cerebral anomalies .Third trimester MRI shows 80% of lissencephaly ,100% of schizencephaly and 73% of polymicrogyria foetuses whose postnatal diagnosis were the same(7). It has been suggested in literature that abnormal

operculization results from underlying cortical dysplasia and those foetuses are at increased risk of refractory epilepsy or developmental delay in postnatal period (8,9,10). Hence knowledge of anatomy of the developing fetal brain is essential to detect abnormalities in prenatal imaging ,since some of the brain malformations are associated with severe developmental anomaly which requires early diagnosis (11).

Although ultrasonography remains the modality for evaluation of antenatal foetus , MRI has been increasingly used in second and third trimesters of pregnancy in foetal brain evaluation (12). In contrast to USG ,visualisation of fetus in MRI is not limited by fetal position, maternal obesity or oligohydramnios and also visualisation of brain is not restricted by ossified skull (13,14). MRI is a boon to antenatal foetus through which we are able to distinguish fetal brain structures such as gyration/sulcation, posterior fossa structures and cerebrospinal fluid spaces through its excellent soft tissue contrast resolution (15). Since brain development is a dynamic process ,it is indeed important to recognize the normal MRI appearance of the brain and its sulcations at different gestational ages to avoid misdiagnosis or missing diagnosis. Our aim of the study is to establish the normal sulcation landmarks at different gestational age by using inutero MR imaging in south Indian population .

ANATOMY OF CEREBRAL SULCI :

Cerebrum is divided in to two large hemispheres which together accounts for 85% of brain mass. The cerebrum forms the superior part of the brain covering the diencephalon and brain stem similar to the way a mushroom covers

the top of its stalk . Elevated ridges of tissue, called gyri (singular: gyrus), separated by shallow groves called sulci (singular: sulcus) mark nearly the entire surface of the cerebral hemispheres. Deeper grooves, called fissures, separates large regions of the brain (16). The fissures correspond to the more well-developed and anatomically constant sulci, and the gyri or convolutions that have a more rounded or quadrangular shape are usually referred to as lobule (17) .

One of the major maturational processes of the human brain is gyration which leads to a significant increase of the cerebral surface (18). Gyration is a unique phenomenon occurring late during foetal development and it goes on to the end of the pregnancy and even later after the birth . The primary sulci appears as shallow grooves on the surface of the brain which becomes progressively and more deeply infolded to develop multiple secondary side branches which are called as secondary sulci .Gyration still proceeds with still more side branches from secondary sulci which are called as tertiary sulci (19,20). In this section we shall discuss the history of neuroanatomical naming of sulci and its anatomical location in brain .

HISTORY :

The middle ages from 4th to 14 th century known to be poor in terms of scientific development in general ,but however after 14th century where prohibition against dissection of cadavers was taken down progressive development of all anatomical knowledge started to ensue. Andreas Vesalius (1514 -1564) , described various structures related to anatomy of brain including white matter and gray matter differentiation (21,22). Although he provided intricate anatomical

descriptions like ventricular cavities, ,illustrations of the brain convolutions are shown by him as in a chaotic arrangement only . Leonardo da vinci (1472-1519) was the one to create beautiful illustrations of the brain surface and Julius casserius (1545-1616) depicted the brain sulci and gyri which was understood to resemble small bowel at that time (22) .

In 1663 Dr.Sylvius who is actually named Franciscus de la boe described the lateral cerebral sulcus which is why therefore known as sylvian fissure(21) . In 1829 Luigi Rolando an Italian anatomist became the first to accurately portray the cerebral sulci including the central sulcus and hence it is sometimes called as Rolandic fissure (23)

In 1851 , Friedrich Arnold recognized the sylvian fissure and parieto occipital sulcus as anatomically constant sulci . However a French anatomist Louis pierre Gratiolet was the first to give accurate descriptions of cerebral fissures and lobes .He was the one to understand and describe the fact that despite individual variations cerebral sulci and gyri are organized in accordance with a general arrangement (23) . In 1869 Alexander ecker accurately described all of the cerebral sulci and gyri introducing orbital , transverse occipital ,parieto-occipital ,precentral sulci (22). William Turner (1832-1916) also one of the anatomist to describe sulci in detail , hence intraparietal sulcus is also called as Turners sulcus . Despite the intense interest , it was only in the middle 19th century cerebral sulci and gyri was perceived and described .

EMBRYOLOGICAL CONSIDERATIONS :

Embryologically , cerebral sulci appear to follow a sequence which actually reflects the phylogenetic hierarchy between them. Fissures appears to develop first followed by sulci containing eloquent areas and is followed by secondary and tertiary sulci (24) .During early embryogenesis ,brain develops from 3 primary vesicles which originated from cephalic end of neural tube ,they are prosencephalon , mesencephalon and rhombencephalon. Mesencephalon forms the midbrain whereas rhombencephalon divides in to metencephalon and myelencephalon to form pons,cerebellum and medulla respectively. Prosencephalon is the primary brain vesicle which divides in to telencephalic (endbrain) and diencephalic (interbrain) vesicles to form the largest part of brain which is cerebral hemisphere with deep grey matter .

Embryologically ,by the 10^{th} week of gestation ,a superior midline depression occurs in the end brain which we later call it as interhemispheric fissure. It is followed by the appearance of transverse fissure which is seen between telencephalic and diencephalic vesicles. It is stated that between 8 – 10th week few transient furrows appear on the cerebral surface but however these are not true precursors of real permanent sulci. Around 5th month of gestation brain surface becomes smooth except for a depression that is seen on either side of insular region .

Embryoloically around 4^{th} to 5 th month of gestation the following sulci begin to appear and are considered to be first identifiable sulci – olfactory sulci, calcarine sulci, parietooccipital sulci, cingulate and central sulci.

Eventhough sulcal development follows a particular sequence genetics also appears to determine the variable final result of sulcal development(25). However, the sulci just evolve through an enormous infolding process while the developing brain entirely undergoes a process of circular curvature, so that to effectively wrap the thalami to make it as its morphological center. Therefore, cereberal sulci in superolateral and inferior surfaces , are directed toward the most proximal portion of the lateral ventricle, whereas the sulci of medial surfaces are influenced by the development of the corpus callosum ,portrayed by the absent cingulate gyrus and presence of radial pattern of the medial surface sulci in case of its congenital absence .

CEREBRAL SULCI - ANATOMICAL LANDMARKS :

1.Interhemispheric fissure :

Interhemispheric fissure otherwise called as medial longitudinal fissure or cerebral fissure .It is the deep groove located in the midline up to the corpus callosum between both cerebral hemisphere and contains falx cerebri .

2. Parietooccipital fissure:

It is one of the important fissure in brain ,which separates parietal lobe from occipital lobe by extending downward and forward as a deep cleft on the medial surface of the brain. Major part of the fissure is visualised on the medial surface of the hemisphere, whereas a small part is seen on the lateral surface. On US images,axial plane at the level of occipital horns is the best plane to view the fissure .It is seen as a small cleft over the bilateral upper margin of the occipital horns of

the lateral ventricles (26) . On MR images ,midline sagittal plane shows the fissure to be in "y" shaped and in axial plane seen as "x" .

3.Callosal sulcus :

Callosal sulcus is a sulcus of brain, located in the medial side of each cerebral hemisphere deep within the medial longitudinal fissure.This sulcus runs posteriorly from genu to the splenium of corpus callosum separating cingulate gyrus dorsally and corpus callosum ventrally .

4.Cingular sulcus :

The cingulate sulcus is completely seen on the medial surface of the brain . It begins under the anterior most end of the corpus callosum and runs upwards and forwards paralleling the rostrum. After that it takes up a parallel course along with the body of the corpus callosum extending up to to the superomedial border of the hemisphere, a short distance behind the upper end of the central sulcus. Because of the curved course of the sulcus, the anterior part is well seen on axial images, and the middle part is best visualized on coronal images (26).

5.Marginal sulcus :

Marginal sulcus is the superior most extension of cingular sulcus on the superomedial aspect of cerebral hemisphere, otherwise called as pars marginalis.This is the sulcus that separates paracentral lobule from precuneus noted in the medial part of cerebral hemisphere .On axial images it is a short sulcus,does

not extend laterally. It acts as an excellent landmark to find out and confirm the location of central sulcus which is usually present one sulcus before the pars marginalis whereas postcentral sulcus is seen posterior to it .

6.Calcarine sulcus :

This fissure is seen on the medial surface of the occipital lobe. It starts from the medial part of the parieto-occipital fissure and extends posteriorly to the occipital pole. On both US and MR images, it is best depicted in a coronal plane through the occipital lobes, where it is seen immediately superior to the tentorium (26) . It also can be identified on sagittal MR images as a linear oblique sulcus running across the occipital lobe in such a way that it divides the occipital lobe in to superior and inferior part .

7. Hippocampal fissure :

Hippocampal fissure also called as hippocampal sulcus is the first hemispheric sulcus to appear phylogenetically .It is the fissure that seperates dentate gyrus from subiculum of parahippocampal gyrus . It is seen in the inferior surface of medial temporal lobe. Hence it is very well visualised in the coronal sections . It is bounded superiorly by cornua ammonis (CA3,CA2) , medially by dentate gyrus and CA4, medially and inferiorly by dentate gyrus and laterally by CA1 and subiculum of parahippocampal gyrus .

8. Collateral sulcus :

Collateral sulcus is on the tentorial surface of the hemisphere and extends from, near the occipital pole to within a short distance of temporal pole. Behind, it lies below and lateral to calcarine fissure ,from which it is separated by lingual gyrus. In front ,it is situated between the parahippocampal gyrus and anterior part of fusiform gyrus. Simply to say collateral sulcus is bounded medially by lingual gyrus posteriorly and parahippocampal gyrus anteriorly and laterally by fusiform gyrus (27) .

9.Occipitotemporal sulcus :

The occipitotemporal sulcus separates the medial border of the inferior temporal gyrus from the lateral border of the fusiform or medial occipitotemporalgyrus (27). It is a sulcus that runs parallel to the collateral sulcus in the inferior surface of temporo-occipital lobe and is separated from collateral sulcus by fusiform gyrus running medially .

10.Superior and inferior frontal sulci :

The superolateral surface of the frontal lobe is indented by two sulci running in a broadly horizontal fashion – they are the superior and inferior frontal sulci. These demarcate the superior frontal gyrus (above the superior frontal sulcus), inferior frontal gyrus (below the inferior frontal sulcus), and middle frontal gyrus

between the two. These are well depicted on coronal MR images. The precise pattern of sulcation varies a great deal, but most frequently the superior frontal sulcus is deficient posteriorly, allowing continuity between the posterior parts of the superior and middle frontal gyri (28) .

The superior frontal sulcus forms the lateral limit of the superior frontal gyrus . Rostral to its point of intersection with the superior precentral sulcus, the superior frontal sulcus runs in a more or less horizontal direction and in its rostral end approaches the midline of the hemisphere. Thus, the rostral end of the superior frontal sulcus is more medially located than its caudal end. The superior frontal sulcus is not a continuous sulcus but consists of two main branches that are either separated on the surface of the brain by an anastamotic fold or can be separated in the depths of the sulcus as can be seen in coronal or horizontal sections. Thus, one may speak of a posterior and an anterior superior frontal sulcus (29) .

The inferior frontal sulcus originates, posteriorly, close to the inferior precentral sulcus and ends approximately at the anterior half of the pars triangularis of inferior frontal gyrus. Its anterior terminal branch may merge superficially with the triangular sulcus. The inferior frontal sulcus may sometimes separate into a posterior and an anterior part. It is sometimes stated, incorrectly, that the inferior frontal sulcus may continue, ventrally, almost as far as the lateral margin of the orbital frontal region. This false impression is the result of the blending of the anterior part of the inferior frontal sulcus with a distinct sulcus that often forms the anterior end of the pars triangularis, the pretriangular sulcus (30).

11.Superior and inferior temporal sulci :

Superior temporal sulcus is a horizontal sulcus of the temporal lobe and it is the sulcus that seperates superior and inferior temporal gyrus.It is the first sulcus seen below the lateral fissure. Garel et al distinguished superior temporal sulcus to have anterior and posterior portions in which anterior portion is said to be located with greater certainity (5) .

The inferior surface of the temporal lobe is a concave surface which posteriorly continues as tentorial surface of occipital lobe . It is longitudinally traversed along the axis of the lobe and it extends from near the occipital pole posteriorly to the temporal pole anteriorly and is frequently subdivided by multiple bridging gyri .

12.Intraparietal sulcus :

It is located in the superolateral surface of parietal lobe . It is situated posterior to the postcentral sulcal complex .In most of the cases by gyral passage it is divided in to anterior and posterior ramus. The sulcus of Jensen usually emerge from the main stem of intrapareital sulcus as a vertically linear deep branch without side branches and is usually seen terminated between first and second caudal branches of superior temporal sulcus (31).

13. Insular sulci :

Insular sulci are the sulci that are present in the insular cortex. The insular

cortex ,otherwise known to be the fifth lobe of brain lies deep to lateral sulcus or sylvian fissure .the overlying cortical areas are formed by frontal ,parietal and temporal lobes (opercula) . The Insula is visualised as a sessile irregular pyramid, with its base facing medially and apex facing laterally as sylvian fissure . It is bounded by four insular/periinsular sulci - anterior, inferior, superior, and posterior .

14. Central sulcus :

Central sulcus which is also called as Rolandic fissure , named after Luigi Rolando .It is the longest horizontal sulcus in superolateral surface of the brain running and entering the interhemispheric fissure. It is said to have shape of inverted omega. Central sulcus can be easily identified just anterior to the pars maginalis which is said to form an open bracket towards central sulcus . This is the sulcus that separates the frontal lobe from parietal lobe .

15.Precentral & Postcentral sulcus :

Precentral sulcus is also a vertical sulcus ,by name itself it is evident that it is anterior and parallel to the central sulcus and post central is posterior to the central sulcus. Hence precentral is located in the frontal lobe and postcentral in parietal lobe. Inferiorly precental sulcus reaches up to sylvian fissure. Postcentral sulcus is the sulcus which separates somatosensory cortex from rest of the parietal lobe whereas precentral sulcus separates motor cortex from rest of the frontal lobe .

II. AIM

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OBJECTIVES

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Aim of this study is to provide a standards of reference that can be used to assess normality of fetal sulcation in inutero fetus using foetal MRI .

OBJECTIVES

1. To determine the usefulness of antenatal MRI in identifying the normal sulcal development .
2. To determine the utility and capability of antenatal MRI in postulating a normogram for sulcal development in antenatal fetuses to estimate the correct gestational age .

III. REVIEW OF LITERATURE

III. REVIEW OF LITERATURE

So far , only limited studies have been done in assessing the normal foetal gyral and sulcal pattern of development using antenatal MRI .

In 1999. Levine and Barnes (32) et al (Boston) were the first authors to assess the cortical maturation of the fetal brain on prenatal MR images . 53 MRI examinations were performed out of which 28 for maternal indications, and therefore imaging planes could not be done in a plane orthogonal to the fetal brain . According to these people , this was described as a bias that could possibly explain a delay in the appearance of sulci and fissures, and they also underlined the need for further studies to still more substantiate their findings. In studies of the maturation or development of the foetal cortex, Determination of gestational age is usually based on mother's last menstrual period and not based on dating scan or early sonographic features . Furthermore , among 53 foetuses who were analyzed by Levine and Barnes , there were six twin pregnancies, which may also constitute bias in the evaluation of cortical development and maturation .

Lan (33) et al , in 2000 , similarly analysed the normal maturation of fetal brain with specific half-Fourier rapid acquisition with relaxation enhancement (RARE) sequence of magnetic resonance (MR) imaging. 25 normal foetuses with maternal indications for undergoing MRI were included n the study . Their gestational age were assigned as per last menstrual period corrected by crown rump length measurement in USG .Foetuses from 12–38 weeks of gestational age examined in utero by MRI . Apart from the sulcal assessment they also assessed grey matter and

white matter differentiation , ratio of diameter of ventricles to brain ventricle-to-brain and also along with the evaluation of size of the subarachnoid space with respect to gestational age. Their results states that , the brain normally has a smooth surface at around 12–23 weeks, and there will be two or three differentiated layers in the cerebral cortex. Then at around 24–26 weeks, a few shallow grooves appear in the central sulcus along with the three layers of cortex namely immature cortex (outer), intermediate zone, and germinal matrix (inner zone) . Only at the age of 27–29 weeks, sulcus formation have been observed in various regions of the brain parenchyma, and only during these weeks the germinal matrix becomes invisible. Sulcation are seen involving whole cerebral cortex starting from 30 weeks of gestational age . However , they stated that, the cortex did not appear to undergo infolding, and also opercular formation was not able to describe before 33 weeks. As far as ventricles is concerned they stated a cut off of 23 weeks before which the cerebral ventricles were usually larger whereas after that they gradually became smaller. The subarachnoid space also was described to be dilated , especially over the cortical convexities in almost all weeks but more marked at 21–26 weeks.

In 2001 ,Garel (5) et al performed antenatal fetal cerebral MR examination in 173 normal Foetuses from 22 to 38 weeks of gestation. Eight sections in coronal , sagittal , and axial slices obtained and analyzed. The sequential development of the almost all fissures and sulci with respect to particular gestational age were hence tabulated. According to him the timetable happened to be in good agreement when compared to neuro anatomic standards of reference ,but with a lag of 1 week .

In the same year of 2001 ,Girarrd (34) et al , selected apparently normal fetuses of number 30 ,and attempted to describe and characterize general anatomic aspects of sulci and gyri development and also described the MR signal intensities of brain during fetal development .

In 2003, Seiji.abe(35) et al also tried to assess the normal fetal sulcation and gyration using antenatal MRI . 109 normal foetuses ungergone MR images from 18 to 39 weeks of gestation . On the proposed basis of the schematic diagrams of the development of sulci and gyri proposed by Chi *et al* (1977) and the basic configuration of the fetal brain described by Dorovini-Zis and Dolman (1977) , they classified the foetal brain maturation based on sulci and gyri development into 8 groups . The classification involved only the developing sulci in the frontal and temporal lobes without including parietal or occipital lobar sulci . And also in protocol, axial images are taken parallel to the plane of line joining anterior and posterior commissure . They also retrospectively discussed the relationship between their classification and McArdle classification which actually contained of five-stages of grey and white matter development . Significant differences could be demonstrated in the gestational age among the 8 groups by them .

In 2003 , Garel (36) again attempted to display the possibilities depicted by fetal MRI especially in the assessment of cerebral biometry,normal myelination and sulcation. Until the last few years, normal gestational landmarks in cerebrum were only assessed by ultrasonographic and if at

all by macroscopic methods (37) . This was the paper which tried to demonstrate the utility of MRI in antenatal imaging .In this study prospective imaging of 225 fetuses were done using a standardised methods. The gestational age included in the study ranged from 22 to 38 weeks. In contrast to imaging in ultrasound,MRI also allows measurements of brain independent of the fetal head position . Their results showed that there can be best correlation between development of sulci and gestational age especially after 28 wks . According to them most of the primary and secondary sulci were present even before 34 wks of gestation .

In 2004 , Malinger (38) did a comparative study of fetal MRI and ultrasound (both transvaginal and transabdominal approach)of fetal brain to evaluate whether fetal brain magnetic resonance imaging (MRI) actually adds any useful information more than that of obtained by dedicated fetal neurosonography using both transabdominal and transvaginal approach in brain anomaly suspected fetuses. In a 2-year period between 42 fetuses underwent both MRI and neurosonographic examinations of the brain.,where there is referral indications like asymmetric ventriculomegaly,periventricular cysts, midline suspicious findings, corpus callosum agenesis , cytomegalovirus infection and others. Similar diagnosis done in total 29 fetuses with both the modalities .However in three of foetuses with a normal ultrasound findings , MRI showed a parenchymal abnormality and also MRI was able provide 3 more accurate diagnosis in that study. But finally this study depicted that MRI is no way superior to exclusive neurosonography .

In same 2004 ,Toi et al (39) conducted a study to know how much early the fetal cerebral sulci can be visible at prenatal ultrasound technique and attempted to describe the normal pattern of fetal sulcal development . They studied 50 normal fetuses as our study for visibility of the cerebral sulci , but in ultrasound . The gestational age of the foetuses studied however ranged from 15 to 29 weeks. According to this study sulci can be seen by transabdominal ultrasound as early as approximately 18 weeks. Medial hemispheric sulci and the insula were able to be described more confidently than convexity sulci. The Earliest visualisation of specific sulci as per gestational age of different sulci are as follows - parieto-occipital fissure at 18.5 weeks , calcarine sulcus at 18.5 weeks, cingulate sulcus at 23.2 weeks and convexity sulci at 23.2 weeks. The gestational age at which the particular sulci were always visible were parieto-occipital fissure at more than 20.5 weeks, calcarine sulcus at more than 1.9 weeks, cingulate sulcus at more than 24.3 weeks and convexity sulci at more than 27.9 weeks. Their ultrasound data were obviously consistent with anatomical studies and also prenatal fetal magnetic resonance imaging findings.

In 2006 , Cohen – sacher (40) et all did a longitudinal study by doing only ultrasound examinations of antenatal foetuses with detailed examination of cerebral cortex and the sulci and gyri development in 22 pregnant women starting from 18 weeks which is done every 2 weeks . This study also confirmed the orderly pattern of occurrence of sulcal development . He demonstrated the first sulci as early as 18 weeks . According to them parietooccipital fissure , cingulate and

calcarine sulci were present between 22–24 weeks. The central sulcus is noted to be present in all cases at 28 weeks .

Whereas in 2008 , Guibaud (41) et all , in his retrospective study of 15 fetuses ,tried to determine the significance of prenatal abnormal sylvian fissure development or otherwise abnormal operculization . Cases having reported as abnormal operculization at 24–34 weeks , using prenatal MRI and whose follow-up data ,available were included in the study . The imaging findings , correlated with microscopic and macroscopic neuropathological data and with postnatal imaging findings. According to this study there were associated abnormal operculization with cortical dysplasia in 4 of 11 pregnancies which was confirmed by microscopic examination .They divided the associated anomalies with abnormal sylvian fissure development but with normal cortical architecture into five groups - like those with microcephaly or frontal hypoplasia , neural tube defects, , glutaric aciduria , other cerebral abnormalities, and extracerebral anomalies.

IV. MATERIALS AND METHODS

1V.MATERIALS AND METHODS

It is a prospective descriptive anatomical study .The study subjects are antenatal mothers between 22 to 36 weeks of gestation. Totally 74 antenatal mothers were included in the study whose obstetric ultrasound examination of the foetuses shows apparently normal findings . The gestational age of the foetuses were determined not by last menstrual period but based on first trimester dating scan age which was enrolled by crown rump length of the fetus . The study subjects of number 74 were selected among our outpatient population who came for routine ultrasound examination and who came for MRI examination for maternal indications in second and third trimester between the study period of August 2016 to June 2017.

In all the selected mothers, screening ultrasound examination was done to confirm the presence of any other organ anomalies and gross neurological anomalies . All the subjects were well informed about the study in their mother tongue and informed consent was got from all mothers . Form F also had been filled up and got signed by study subjects .

The inclusion criteria for our study were antenatal mothers with gestational age between 22 – 36 weeks who should have done atleast once ,the dating scan in first trimester i.e less than 12 weeks , antenatal mothers whose ultrasound examination shows apparently normal foetus and give complete informed consent to do fetal MRI. Pregnant mothers who came for MRI examination with past family history of epilepsy, gyrational abnormalities, past history of mentally retarded child whose present intrauterine foetus shows apparently normal findings in ultrasonogram ,

obese mothers in whom ultrasound may not be useful to assess the foetus well being . High risk pregnancy with complications like pregnancy induced hypertension ,gestational diabetes were excluded from the study since it may adulterate the assessment of normal cerebral sulcal development due to high possibility of intrauterine growth restriction . Twin gestation also was excluded from the study .

MRI examination was done in the early morning session in overnight fasting status . Mothers were instructed to empty the bladder before MRI examination only to reduce foetal movements to some extent. No other medication or sedation was given .

Foetal MRI was performed using 1.5 tesla superconducting magnet SIEMENS SYMPHONY SYNGOMR (no.1006992119) using a phased array torso surface coil . Basic sequence used in our study was half fourier acquired single shot turbo spin echo , which is a type T2 spin echo sequence (single shot fast spin echo sequence) ,So as to reduce the movement artifacts created by foetal movements and to improve image quality .

Initially localizer is obtained with large field of view ranging from 320–400 mm to assess the foetal position in three orthogonal planes . Once scout image was taken ,based on the position of foetal head serial images in all three planes were taken which should set to be alligned orthogonal to fetal brain using following parameters - 1.Slice thickness was kept as 4 – 6 mm . 2. Matrix size 169x256 3.field of view of 330-360 4. Flip angle of 90 degrees with acquisition time

of 1 slice per sec . About 9 to 19 slice of images were obtained with interslice thickness of less than 2 mm .

SULCI	**BEST VISUALISATION**
Interhemispheric fissure	CORONAL > AXIAL
Callosal sulcus	SAG > CORONAL
Parietooccipital fissure	SAG > AXIAL > CORONAL
Cingular sulcus	SAG > COR
Secondary cingular sulci	COR > SAG
Marginal sulcus	AXIAL > SAG
Calcarine fissure	SAG > AXIAL > CORONAL
Secondary occipital sulci	COR > SAG > AXIAL
Sulci of the ventral cerebral surface	
Hippocampic fissure	COR > AXIAL
Collateral sulcus	COR > AXIAL
Occipitotemporal sulcus	COR > AXIAL
Sulci of the lateral cerebral surface	
Superior frontal sulcus	COR > AXIAL
Inferior frontal sulcus	COR > AXIAL
Superior temporal sulcus (posterior part)	COR > SAG
Superior temporal sulcus (anterior part)	COR>SAG
Inferior temporal sulcus	COR>SAG
Intraparietal sulcus	COR> AXIAL
Insular sulci	AXIAL > COR >SAG
Sulci of the vertex	
Central sulcus	AXIAL > SAG
Precentral sulcus	AXIAL > SAG
Postcentral sulcus	AXIAL > SAG

Table 4.1 shows priority of cut sections in which specific sulci can be visualised better

All the images were well scrutinized and examined under the guidence of two eminent radiologists with 5 years of experience in MRI from our department without the knowledge of gestational age of the foetus. All the cerebral sulci were looked for in an orderly manner starting from sulci present in medial cerebral surface,followed by ventral cerebral surface and then those present in vertex . The identified sulci were categorized in to three catagories – present, absent and partially developed . Sulcus which may be seen as a very shallow indentation without a clear CSF space in between are termed as partially developed. Sulcus which is well conspicuous with a clear CSF space in between were termed as present. Each of the sulci may be visualised better in specific orthogonal plane. Those planes are described in the Table 4.1 . In our study, the side of the sulci and sex of the foetus were not discriminated .

V. STATISTICAL ANALYSIS AND RESULTS

V.STATISTICAL ANALYSIS

The collected data were analysed with IBM.SPSS statistics software 23.0 Version. To describe about the data descriptive statistics frequency analysis, percentage analysis were used for categorical variables and the mean & S.D were used for continuous variables. To find the significance in categorical data Chi-Square test was used. In the above statistical tool the probability value .05 is considered as significant level.

AGE DISTRIBUTION :

Age of the antenatal mothers included in the study varies from 18 years to 39 years .Hence mean and median age of the antenatal mothers age are 24.3 and 23 years respectively . The minimum age of antenatal mothers during marriage is 16 years and maximum is 30 years hence mean and median of them are 20 .9 years and 20 years respectively .

		AGE	Married at the age of
N	Valid	74	74
	Missing	0	0
Mean		24.35	20.92
Median		23.00	20.00
Std. Deviation		4.384	3.042
Range		21	14
Minimum		18	16
Maximum		39	30

Table 5.1 shows frequency distribution of age of antenatal mothers and their age at marriage .

PARITY :

PARITY

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	MULTI	48	64.9	64.9	64.9
	PRIMI	26	35.1	35.1	100.0
	Total	74	100.0	100.0	

Table 5.2 shows distribution of parity among the antenatal mothers

Among the 74 antenatal mothers , 26 of them are primi and 48 of them are multiparous women.

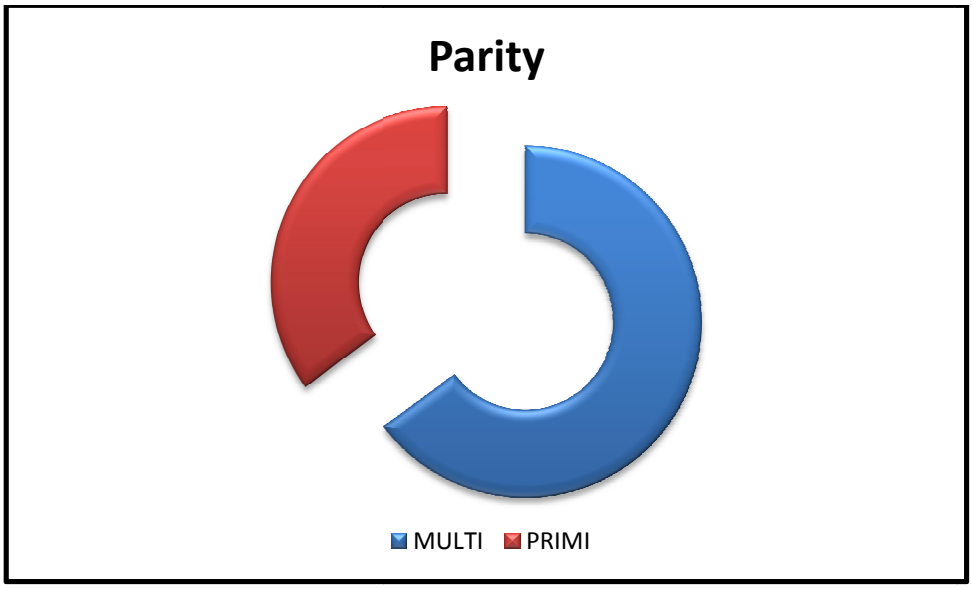


Fig 5.1 Pie chart shows distribution of parity

GESTATIONAL AGE :

Gestational age of the mothers ranging from 22 wks to 36 weeks are grouped in to 7 groups that is 22- 23wks , 24-25wks , 26 -27 wks ,28-29 wks ,30-31 wks ,32-33 wks and more than or equal to 34 wks . Their respective number of occurence (frequency) are 11 ,11 ,8 ,10,10, 10 ,14 in number .

GESTATIONAL AGE					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	22 - 23 W	11	14.9	14.9	14.9
	24 - 25 W	11	14.9	14.9	29.7
	26 - 27 W	8	10.8	10.8	40.5
	28 - 29 W	10	13.5	13.5	54.1
	30 - 31 W	10	13.5	13.5	67.6
	32 - 33 W	10	13.5	13.5	81.1
	>= 34 W	14	18.9	18.9	100.0
	Total	74	100.0	100.0	

Table 5.3 shows distribution of based on gestational age

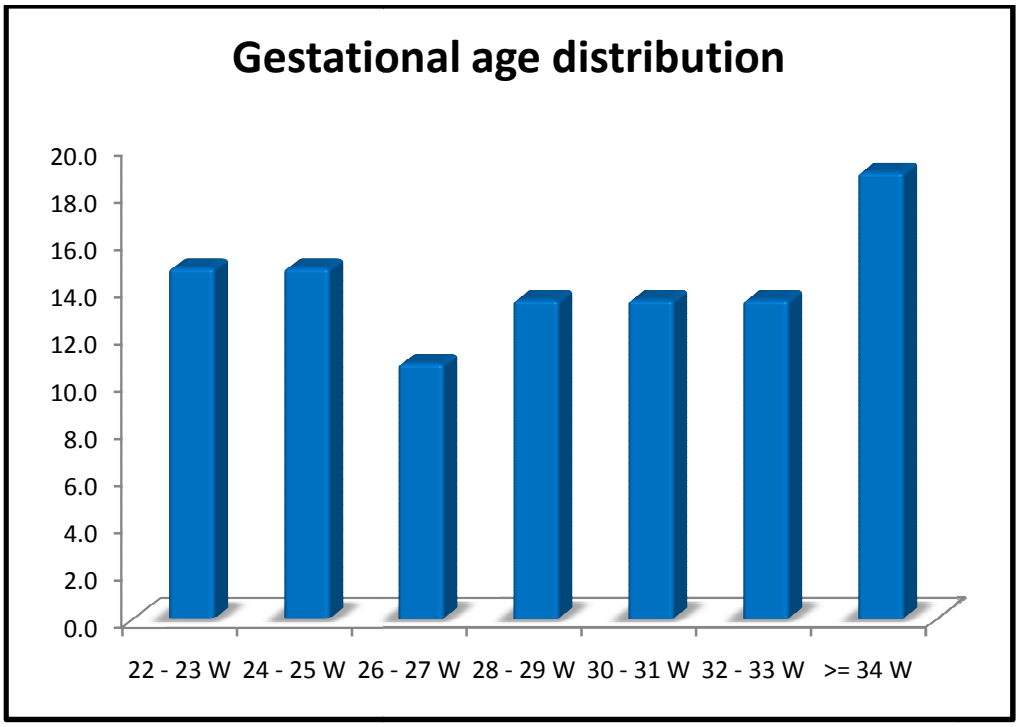


Fig 5.2 Barchart shows distribution based on gestational age

SPECIFIC SULCI :

Frequency table of occurence of interhemisphericfissure ,callosal sulcus and hippocampic fissure are given below . All these sulci are present even in the earliest group of gestational age that is even in the 22 -23 weeks of gestation of gestational age hence their significance in determining the gestational age cannot be statistically proved .

Interhemispheric fissure					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	P	74	100.0	100.0	100.0

Table 5.4 shows frequency table of interhemispheric fissure

Callosal sulcus:					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	P	74	100.0	100.0	100.0

Table 5.5 shows frequency table of callosal sulcus

Hippocampic fissure :					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	P	74	100.0	100.0	100.0

Table 5.6 shows frequency table of hippocampic fissure .

Parieto occipital fissure :

Parietooccipital fissure					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	H	1	1.4	1.4	1.4
	P	73	98.6	98.6	100.0
	Total	74	100.0	100.0	

Table 5.7 shows frequency table of parieto occipital sulcus .

Crosstab					
			Parietooccipital fissure		Total
			H	P	
GA	22 - 23 W	Count	1	10	11
		%	100.0%	13.7%	14.9%
	24 - 25 W	Count	0	11	11
		%	0.0%	15.1%	14.9%
	26 - 27 W	Count	0	8	8
		%	0.0%	11.0%	10.8%
	28 - 29 W	Count	0	10	10
		%	0.0%	13.7%	13.5%
	30 - 31 W	Count	0	10	10
		%	0.0%	13.7%	13.5%
	32 - 33 W	Count	0	10	10
		%	0.0%	13.7%	13.5%
	>= 34 W	Count	0	14	14
		%	0.0%	19.2%	18.9%
Total		Count	1	73	74
		%	100.0%	100.0%	100.0%

Table 5.8 shows comparison of gestational age and parietooccipital fissure .

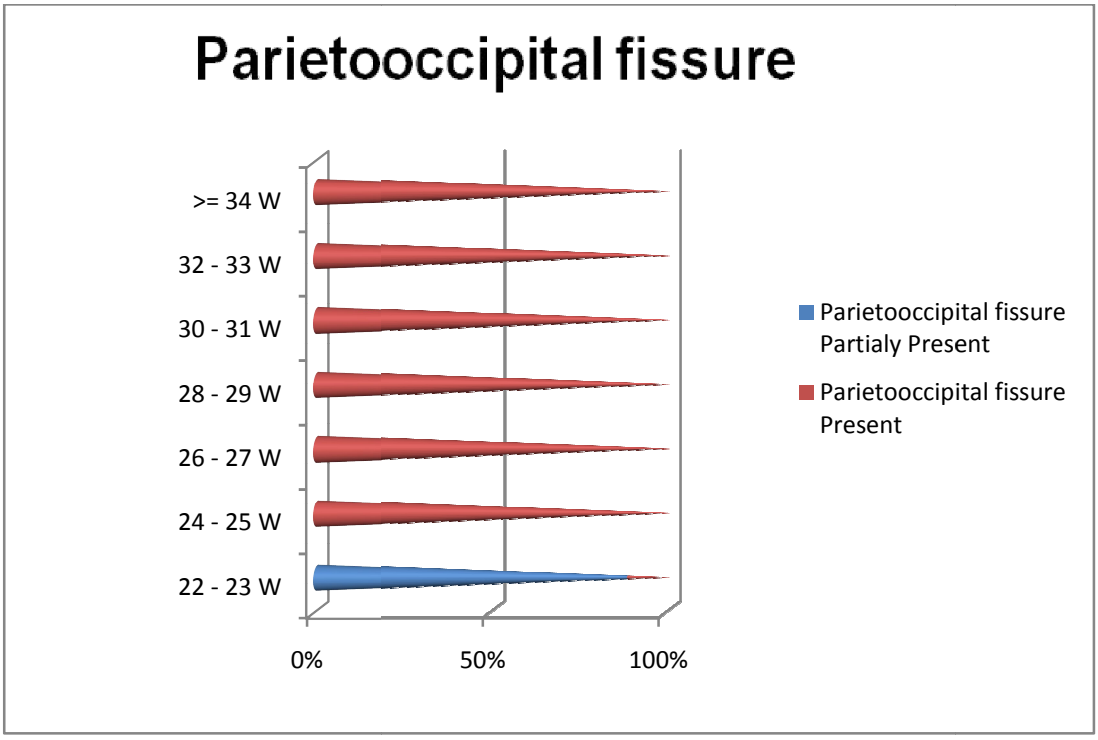


Fig 5.3 Chart shows observed sequential presence of parieto occipital fissure (but statistically not significant)

Chi-Square Tests			
	Value	df	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	5.806[a]	6	**.445**
Likelihood Ratio	3.893	6	.691
N of Valid Cases	74		
a. 7 cells (50.0%) have expected count less than 5. The minimum expected count is .11.			

Table 5.9 shows chi square test - comparison of gestational age and parietooccipital fissure.

The above given table shows the comparison between Gestational age and Parietooccipital fissure which is not statistically significant with P = 0.445 > 0.05 .

CINGULAR SULCUS :

The below given table shows the comparison between Gestational age and Cingular sulcus which is highly statistically significant with P = 0.0005 < 0.01.

Cingular sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	10	13.5	13.5	13.5
	H	5	6.8	6.8	20.3
	P	59	79.7	79.7	100.0
	Total	74	100.0	100.0	

Table 5.10 shows frequency table of cingular sulcus .

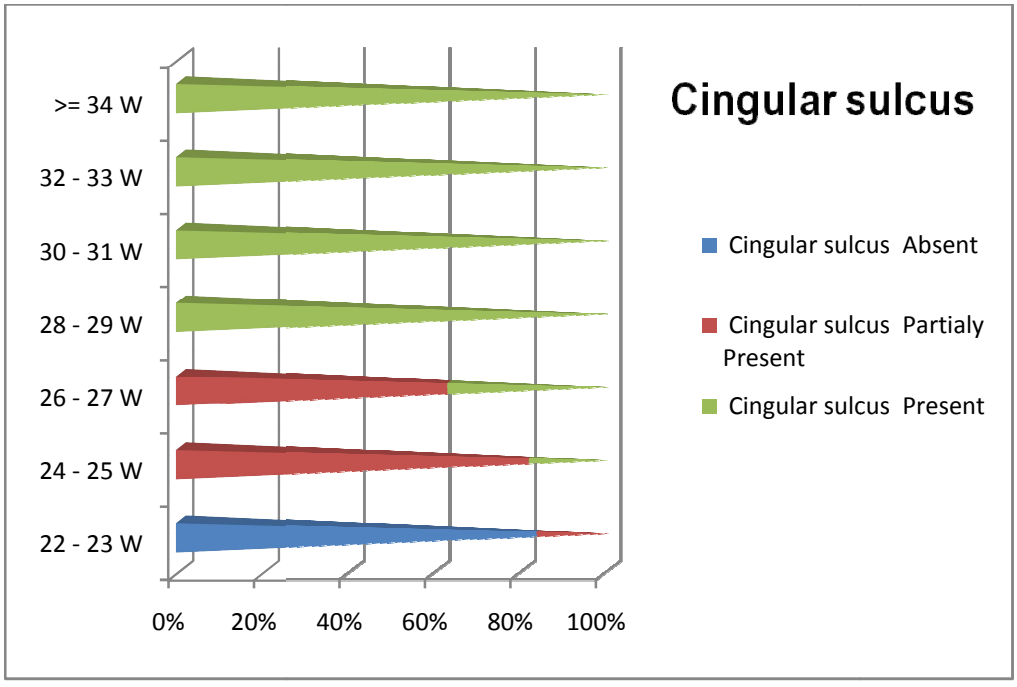


Fig 5.4 Chart shows observed sequential presence of cingularsulcus . (Statistically highly significant

Crosstab						
			Cingular sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	10	1	0	11
		%	100.0%	20.0%	0.0%	14.9%
	24 - 25 W	Count	0	3	8	11
		%	0.0%	60.0%	13.6%	14.9%
	26 - 27 W	Count	0	1	7	8
		%	0.0%	20.0%	11.9%	10.8%
	28 - 29 W	Count	0	0	10	10
		%	0.0%	0.0%	16.9%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	16.9%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	16.9%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	23.7%	18.9%
Total		Count	10	5	59	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.11 shows comparison of gestational age and cingular sulcus .

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	78.743[a]	12	.0005
Likelihood Ratio	68.085	12	.000
N of Valid Cases	74		
a. 14 cells (66.7%) have expected count less than 5. The minimum expected count is .54.			

Table 5.12 shows chisquare test - comparison of gestational age and cingular sulcus .

Likewise for all the following sulci ,chi square test is performed and is found to give significant p value of $0.0005 < 0.01$.

SECONDARY CINGULAR SULCUS :

Secondary cingular sulci

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	45	60.8	60.8	60.8
	P	29	39.2	39.2	100.0
	Total	74	100.0	100.0	

Table 5.13 shows frequency table of secondary cingular sulcus .

Crosstab					
			Secondary cingular sulci		Total
			A	P	
GA	22 - 23 W	Count	11	0	11
		%	24.4%	0.0%	14.9%
	24 - 25 W	Count	11	0	11
		%	24.4%	0.0%	14.9%
	26 - 27 W	Count	8	0	8
		%	17.8%	0.0%	10.8%
	28 - 29 W	Count	10	0	10
		%	22.2%	0.0%	13.5%
	30 - 31 W	Count	5	5	10
		%	11.1%	17.2%	13.5%
	32 - 33 W	Count	0	10	10
		%	0.0%	34.5%	13.5%
	>= 34 W	Count	0	14	14
		%	0.0%	48.3%	18.9%
Total		Count	45	29	74
		%	100.0%	100.0%	100.0%

Table 5.14 shows comparison of gestational age and secondarycingular sulcus .

7 cells (50.0%) have expected count less than 5. The minimum expected count is 3.14.

Using chi square test comparison between gestational age and presence and absence of

secondary cingular sulcus is done and is statistically significant with p = 0.0005 <0.01.

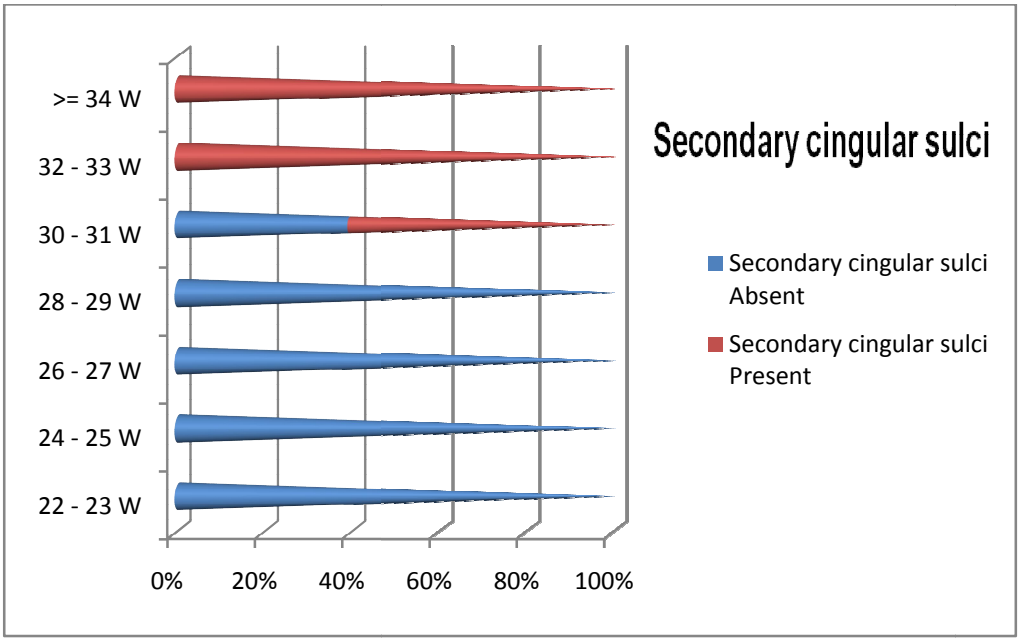


Fig 5.5 Chart shows observed sequential presence of secondary cingularsulcus . (Statistically highly significant)

MARGINAL SULCUS :

Marginal sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	26	35.1	35.1	35.1
	H	1	1.4	1.4	36.5
	P	47	63.5	63.5	100.0
	Total	74	100.0	100.0	

Table 5.15 shows frequency table of marginal sulcus .

Crosstab						
			Marginal sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	42.3%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	42.3%	0.0%	0.0%	14.9%
	26 - 27 W	Count	4	1	3	8
		%	15.4%	100.0%	6.4%	10.8%
	28 - 29 W	Count	0	0	10	10
		%	0.0%	0.0%	21.3%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	21.3%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	21.3%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	29.8%	18.9%
Total		Count	26	1	47	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.16 shows comparison of gestational age and marginal sulcus

14 cells (66.7%) have expected count less than 5. The minimum expected count is .11.

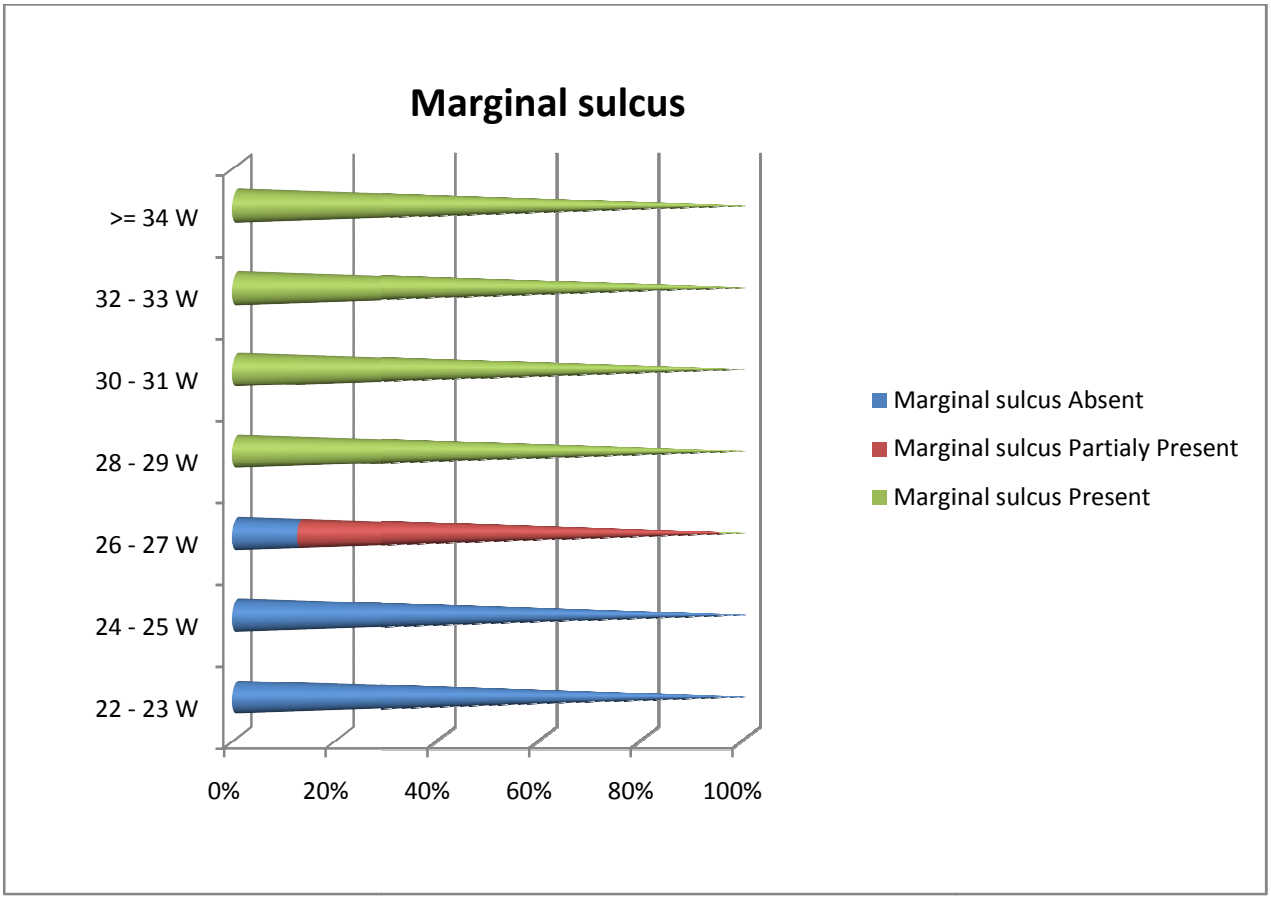


Fig 5.6 Chart shows observed sequential presence of marginal sulcus . (Statistically highly significant)

The comparison between Gestational age and presence and absence of marginal sulcus using chi square test shows p value of 0.0005 < 0.01.

CALCARINE FISSURE *:*

Calcarine fissure

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	18	24.3	24.3	24.3
	H	4	5.4	5.4	29.7
	P	52	70.3	70.3	100.0
	Total	74	100.0	100.0	

Table 5.17 shows frequency table of calcarinefissure .

Crosstab						
			Calcarine fissure			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	61.1%	0.0%	0.0%	14.9%
	24 - 25 W	Count	7	1	3	11
		%	38.9%	25.0%	5.8%	14.9%
	26 - 27 W	Count	0	3	5	8
		%	0.0%	75.0%	9.6%	10.8%
	28 - 29 W	Count	0	0	10	10
		%	0.0%	0.0%	19.2%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	19.2%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	19.2%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	26.9%	18.9%
Total		Count	18	4	52	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.18 shows comparison of gestational age and calcarine fissure

14 cells (66.7%) have expected count less than 5. The minimum expected count is .43.

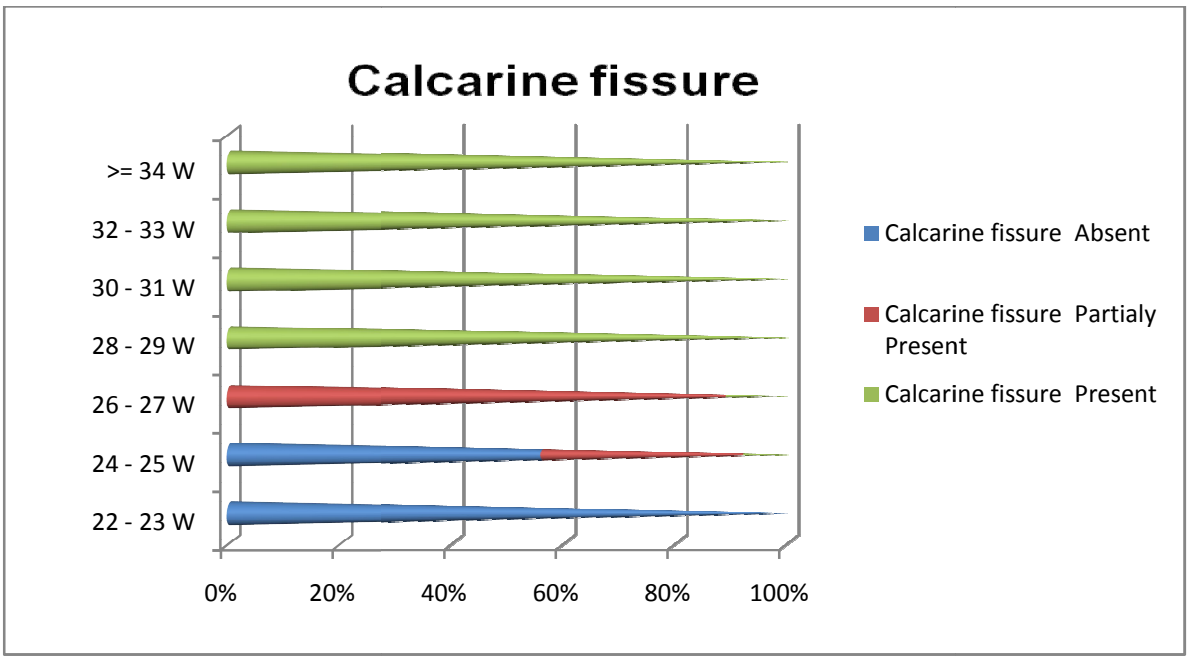


Fig 5.7 Chart shows observed sequential presence of calcarine fissure . (Statistically highly significant)

The comparison between Gestational age and presence and absence of calcarine fissure shows P of 0.0005 < 0.01.

SECONDARY OCCIPITAL SULCI :

Secondary occipital sulci

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	56	75.7	75.7	75.7
	H	5	6.8	6.8	82.4
	P	13	17.6	17.6	100.0
	Total	74	100.0	100.0	

Table 5.19 shows frequency table of secondary occipital sulci .

Crosstab						
			Secondary occipital sulci			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	19.6%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	19.6%	0.0%	0.0%	14.9%
	26 - 27 W	Count	8	0	0	8
		%	14.3%	0.0%	0.0%	10.8%
	28 - 29 W	Count	10	0	0	10
		%	17.9%	0.0%	0.0%	13.5%
	30 - 31 W	Count	10	0	0	10
		%	17.9%	0.0%	0.0%	13.5%
	32 - 33 W	Count	6	3	1	10
		%	10.7%	60.0%	7.7%	13.5%
	>= 34 W	Count	0	2	12	14
		%	0.0%	40.0%	92.3%	18.9%
Total		Count	56	5	13	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.20 shows comparison of gestational age and secondary occipital sulci

14 cells (66.7%) have expected count less than 5. The minimum expected count is .54.

(P = 0.0005 < 0.01. – using chi square test)

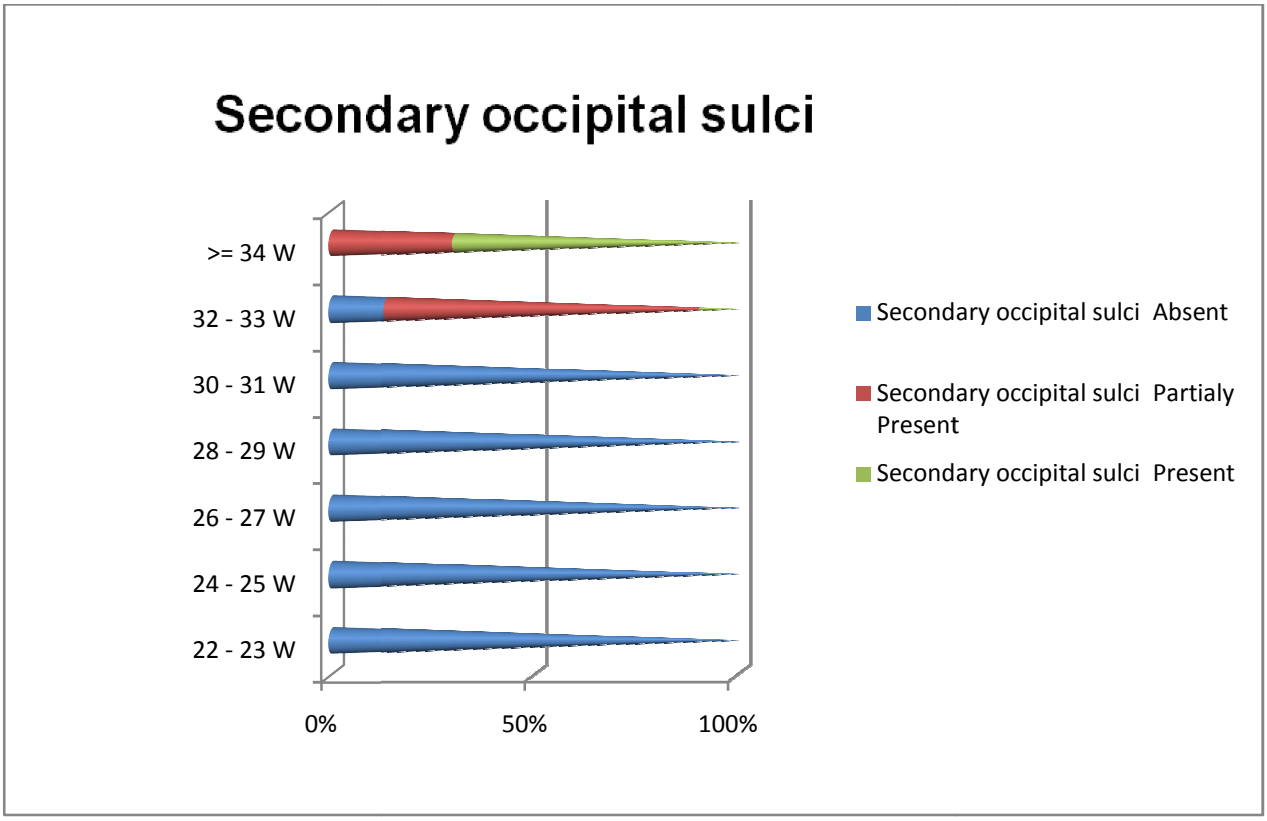


Fig 5.8 Chart shows observed sequential presence of secondary occipital sulci . (Statistically highly significant)

COLLATERAL SULCUS :

Collateral sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	26	35.1	35.1	35.1
	H	4	5.4	5.4	40.5
	P	44	59.5	59.5	100.0
	Total	74	100.0	100.0	

Table 5.21 shows frequency table of collateral sulci .

Crosstab						
			Collateral sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	42.3%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	42.3%	0.0%	0.0%	14.9%
	26 - 27 W	Count	4	1	3	8
		%	15.4%	25.0%	6.8%	10.8%
	28 - 29 W	Count	0	3	7	10
		%	0.0%	75.0%	15.9%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	22.7%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	22.7%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	31.8%	18.9%
Total		Count	26	4	44	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.22 shows comparison of gestational age and collateral sulci

15 cells (71.4%) have expected count less than 5. The minimum expected count is .43.

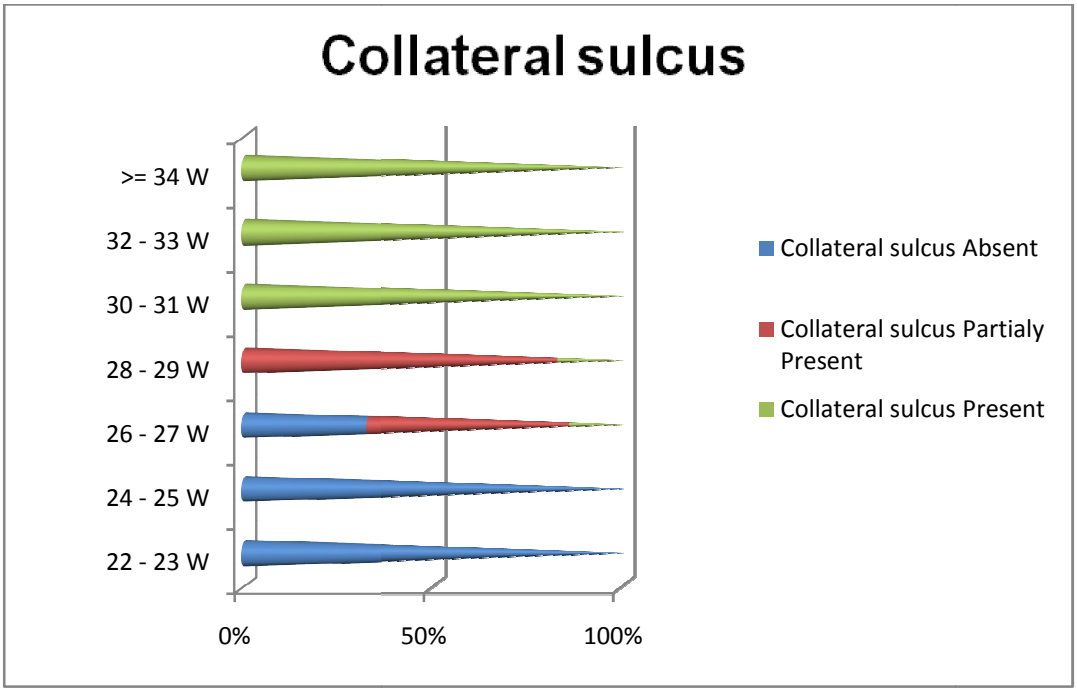


Fig 5.9 Chart shows observed sequential presence of collateral sulcus . (Statistically highly significant)

The comparison between Gestational age and collateral sulcus using chi square test gives P vaue of 0.0005 < 0.01.

OCCIPITOTEMPORAL SULCUS :

Occipitotemporal sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	40	54.1	54.1	54.1
	H	12	16.2	16.2	70.3
	P	22	29.7	29.7	100.0
	Total	74	100.0	100.0	

Table 5.23 shows frequency table of occipitotemporalsulci .

Crosstab						
			Occipitotemporal sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	27.5%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	27.5%	0.0%	0.0%	14.9%
	26 - 27 W	Count	8	0	0	8
		%	20.0%	0.0%	0.0%	10.8%
	28 - 29 W	Count	5	5	0	10
		%	12.5%	41.7%	0.0%	13.5%
	30 - 31 W	Count	5	5	0	10
		%	12.5%	41.7%	0.0%	13.5%
	32 - 33 W	Count	0	2	8	10
		%	0.0%	16.7%	36.4%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	63.6%	18.9%
Total		Count	40	12	22	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.24 shows comparison of gestational age and occipitotemporal sulci

15 cells (71.4%) have expected count less than 5. The minimum expected count is 30.

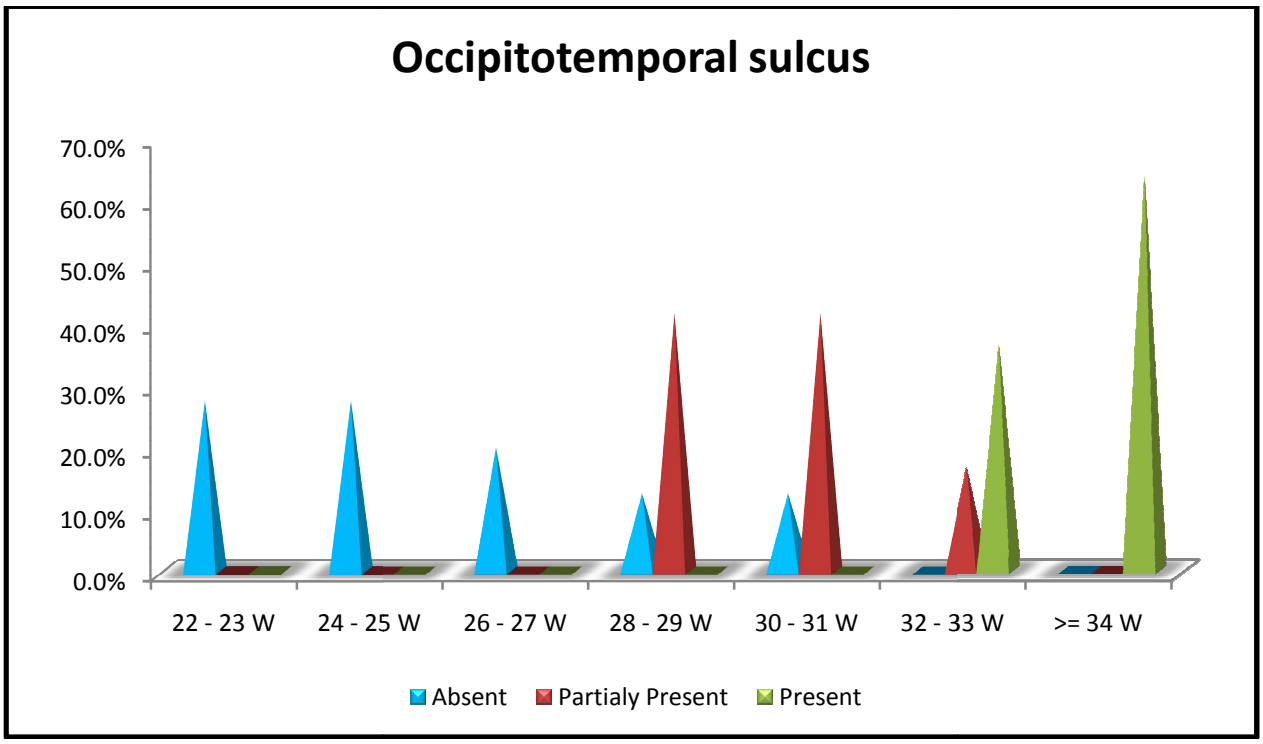


Fig 5.10 Chart shows observed sequential presence of occipitotemporal sulcus .

The comparison between Gestational age and occipitotemporal sulci using chi square test gives P value of 0.0005 < 0.01.

SUPERIOR FRONTAL SULCUS :

Superior frontal sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	32	43.2	43.2	43.2
	H	3	4.1	4.1	47.3
	P	39	52.7	52.7	100.0
	Total	74	100.0	100.0	

Table 5.25 shows frequency table of superior frontal sulcus .

Crosstab						
			Superior frontal sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	34.4%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	34.4%	0.0%	0.0%	14.9%
	26 - 27 W	Count	8	0	0	8
		%	25.0%	0.0%	0.0%	10.8%
	28 - 29 W	Count	2	3	5	10
		%	6.3%	100.0%	12.8%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	25.6%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	25.6%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	35.9%	18.9%
Total		Count	32	3	39	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.26 shows comparison of gestational age and superior frontal sulci

14 cells (66.7%) have expected count less than 5. The minimum expected count is .32.

The comparison between Gestational age and presence and absence of superior frontal sulcus using chi aquare test shows P value of 0.0005 < 0.01.

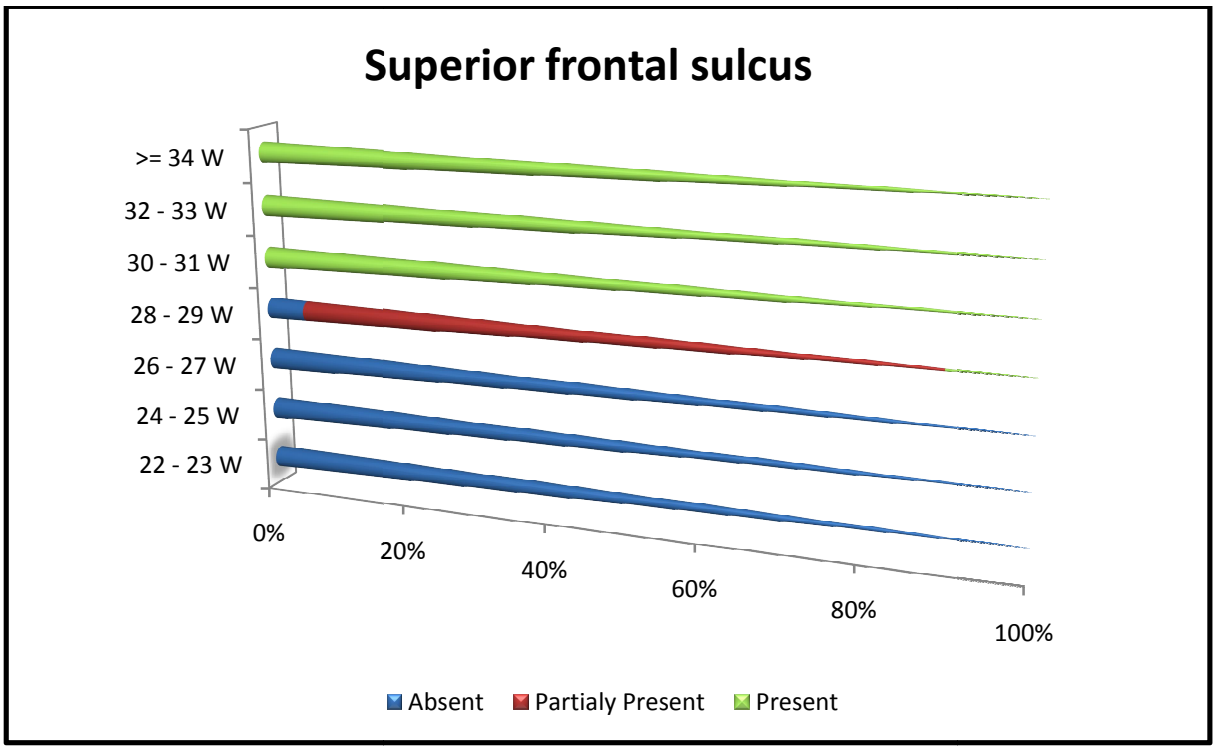


Fig 5.11 Chart shows observed sequential presence of superior frontal sulcus . (Statistically highly significant)

INFERIOR FRONTAL SULCUS :

Inferior frontal sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	32	43.2	43.2	43.2
	H	8	10.8	10.8	54.1
	P	34	45.9	45.9	100.0
	Total	74	100.0	100.0	

Table 5.27 shows frequency table of inferior frontal sulcus .

Crosstab						
			Inferior frontal sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	34.4%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	34.4%	0.0%	0.0%	14.9%
	26 - 27 W	Count	8	0	0	8
		%	25.0%	0.0%	0.0%	10.8%
	28 - 29 W	Count	2	3	5	10
		%	6.3%	37.5%	14.7%	13.5%
	30 - 31 W	Count	0	5	5	10
		%	0.0%	62.5%	14.7%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	29.4%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	41.2%	18.9%
Total		Count	32	8	34	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.28 shows comparison of gestational age and inferior frontal sulci

.

17 cells (81.0%) have expected count less than 5. The minimum expected count is .86.

The comparison between Gestational age and presence and absence of inferior frontal sulcus using chi square test shows P value of $0.0005 < 0.01$.

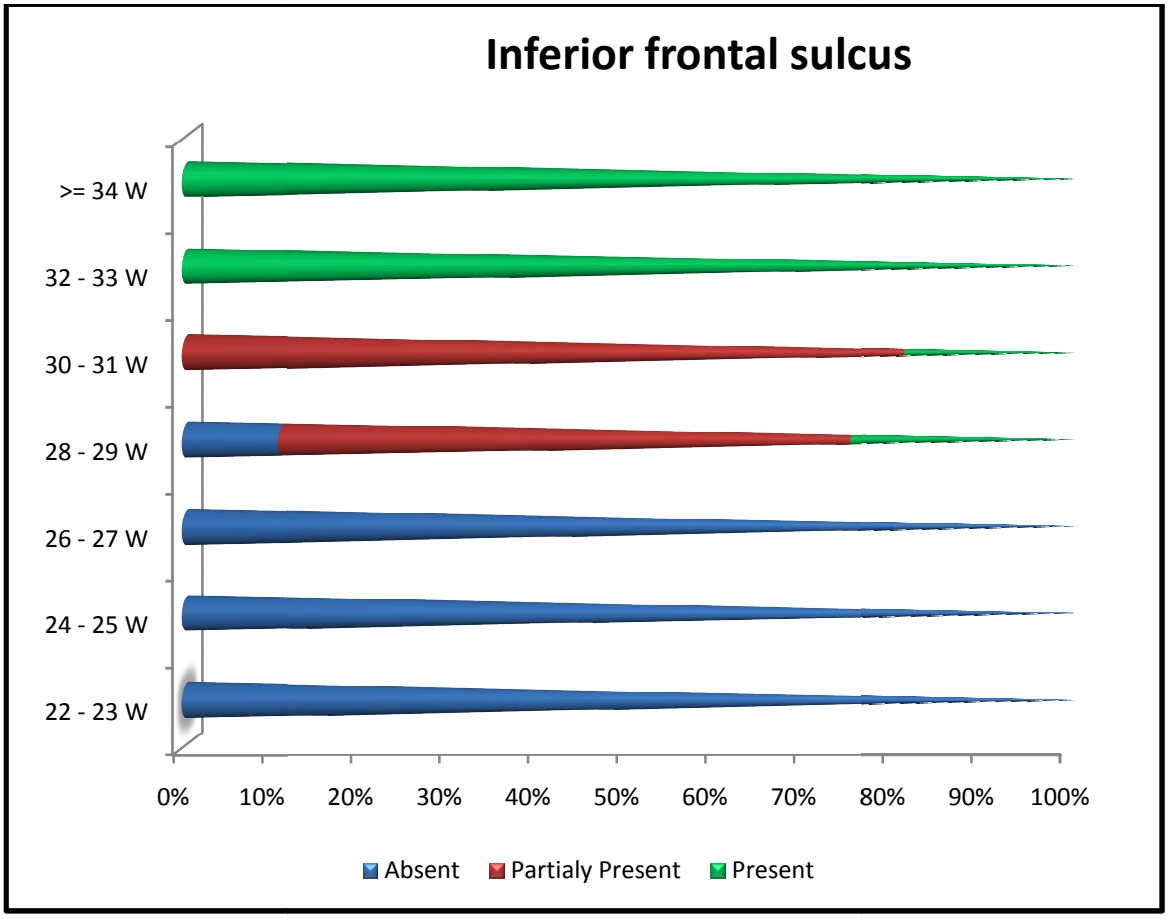


Fig 5.12 Chart shows observed sequential presence of inferior frontal sulcus . (Statistically highly significant)

SUPERIOR TEMPORAL SULCUS :

Superior temporal sulcus (posterior part)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	26	35.1	35.1	35.1
	H	2	2.7	2.7	37.8
	P	46	62.2	62.2	100.0
	Total	74	100.0	100.0	

Table 5.29 shows frequency table of superior temporal (posterior part) sulcus .

Superior temporal sulcus (anterior part)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	41	55.4	55.4	55.4
	H	10	13.5	13.5	68.9
	P	23	31.1	31.1	100.0
	Total	74	100.0	100.0	

Table 5.30 shows frequency table of superior temporal (anterior part) sulcus

.

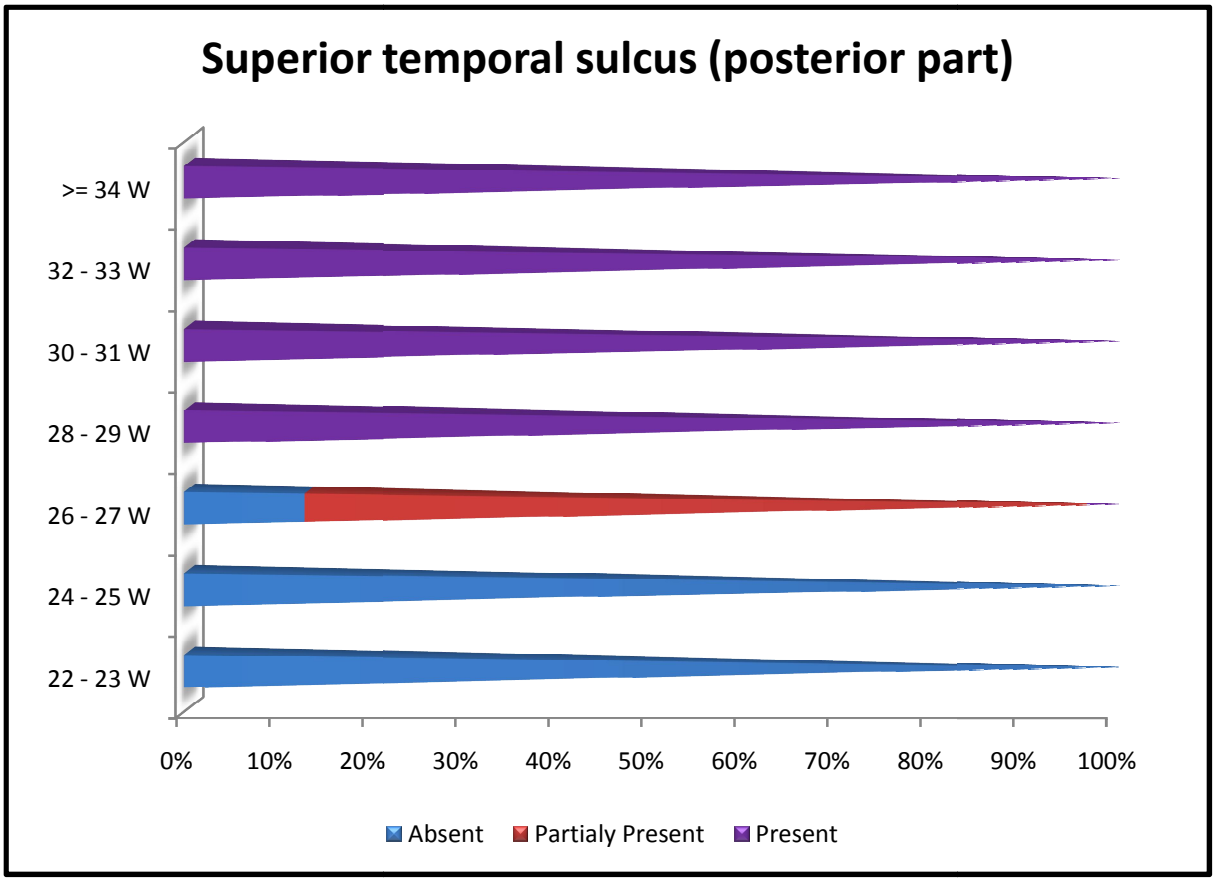


Fig 5.13 Chart shows observed sequential presence of superior temporal (posterior part) sulcus (Statistically highly significant)

Crosstab						
			Superior temporal sulcus (posterior part)			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	42.3%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	42.3%	0.0%	0.0%	14.9%
	26 - 27 W	Count	4	2	2	8
		%	15.4%	100.0%	4.3%	10.8%
	28 - 29 W	Count	0	0	10	10
		%	0.0%	0.0%	21.7%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	21.7%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	21.7%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	30.4%	18.9%
Total		Count	26	2	46	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.31 shows comparison of gestational age and superior temporal (posterior part) sulcus .

15 cells (71.4%) have expected count less than 5. The minimum expected count is .22.

Crosstab						
			Superior temporal sulcus (anterior part)			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	26.8%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	26.8%	0.0%	0.0%	14.9%
	26 - 27 W	Count	8	0	0	8
		%	19.5%	0.0%	0.0%	10.8%
	28 - 29 W	Count	5	5	0	10
		%	12.2%	50.0%	0.0%	13.5%
	30 - 31 W	Count	5	3	2	10
		%	12.2%	30.0%	8.7%	13.5%
	32 - 33 W	Count	1	2	7	10
		%	2.4%	20.0%	30.4%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	60.9%	18.9%
Total		Count	41	10	23	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.32 shows comparison of gestational age and superior temporal (anterior part) sulcus

The comparison between Gestational age and presence and absence of anterior and posterior part of superior temporal sulcus gives P value of 0.0005 < 0.01.

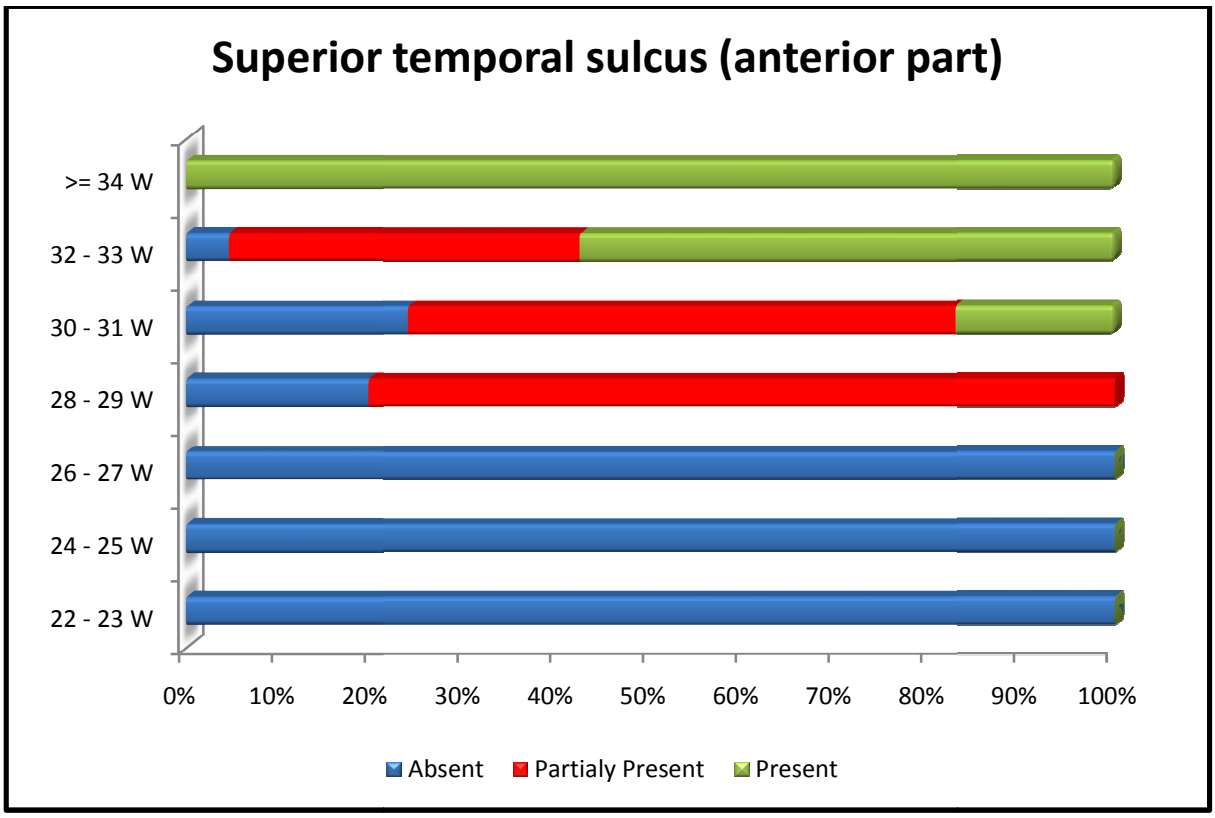


Fig 5.14 Chart shows observed sequential presence of superior temporal (anterior part) sulcus . (Statistically highly significant)

INFERIOR TEMPORAL SULCUS :

Inferior temporal sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	49	66.2	66.2	66.2
	H	9	12.2	12.2	78.4
	P	16	21.6	21.6	100.0
	Total	74	100.0	100.0	

Table 5.33 shows frequency table of inferior temporal sulcus .

Crosstab						
			Inferior temporal sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	22.4%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	22.4%	0.0%	0.0%	14.9%
	26 - 27 W	Count	8	0	0	8
		%	16.3%	0.0%	0.0%	10.8%
	28 - 29 W	Count	10	0	0	10
		%	20.4%	0.0%	0.0%	13.5%
	30 - 31 W	Count	7	2	1	10
		%	14.3%	22.2%	6.3%	13.5%
	32 - 33 W	Count	2	5	3	10
		%	4.1%	55.6%	18.8%	13.5%
	>= 34 W	Count	0	2	12	14
		%	0.0%	22.2%	75.0%	18.9%
Total		Count	49	9	16	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.34 shows comparison of gestational age and inferior temporal sulcus .

14 cells (66.7%) have expected count less than 5. The minimum expected count is .97.

The comparison between Gestational age and presence and absence of inferior temporal sulcus gives P value of 0.0005 < 0.01.

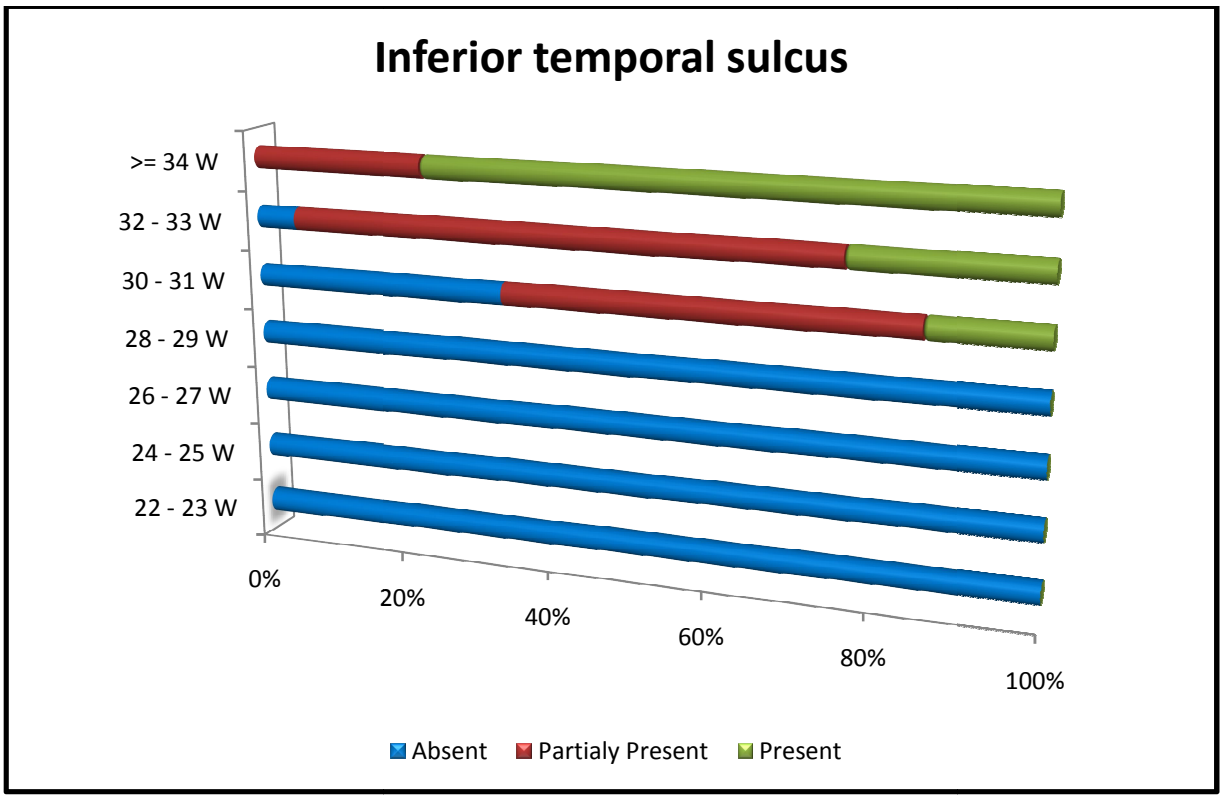


Fig 5.15 Chart shows observed sequential presence of inferior temporal sulcus . (Statistically highly significant)

INTRAPARIETAL SULCUS :

Intraparietal sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	30	40.5	40.5	40.5
	H	3	4.1	4.1	44.6
	P	41	55.4	55.4	100.0
	Total	74	100.0	100.0	

Table 5.35 shows frequency table of intraparietal sulcus .

Crosstab						
			Intraparietal sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	36.7%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	36.7%	0.0%	0.0%	14.9%
	26 - 27 W	Count	8	0	0	8
		%	26.7%	0.0%	0.0%	10.8%
	28 - 29 W	Count	0	3	7	10
		%	0.0%	100.0%	17.1%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	24.4%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	24.4%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	34.1%	18.9%
Total		Count	30	3	41	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5. 36 shows comparison of gestational age and intraparietal sulcus .

14 cells (66.7%) have expected count less than 5. The minimum expected count is .32

.The comparison between Gestational age and presence and absence of intraparietal sulcus , shows statistically significant value $P = 0.0005 < 0.01$.

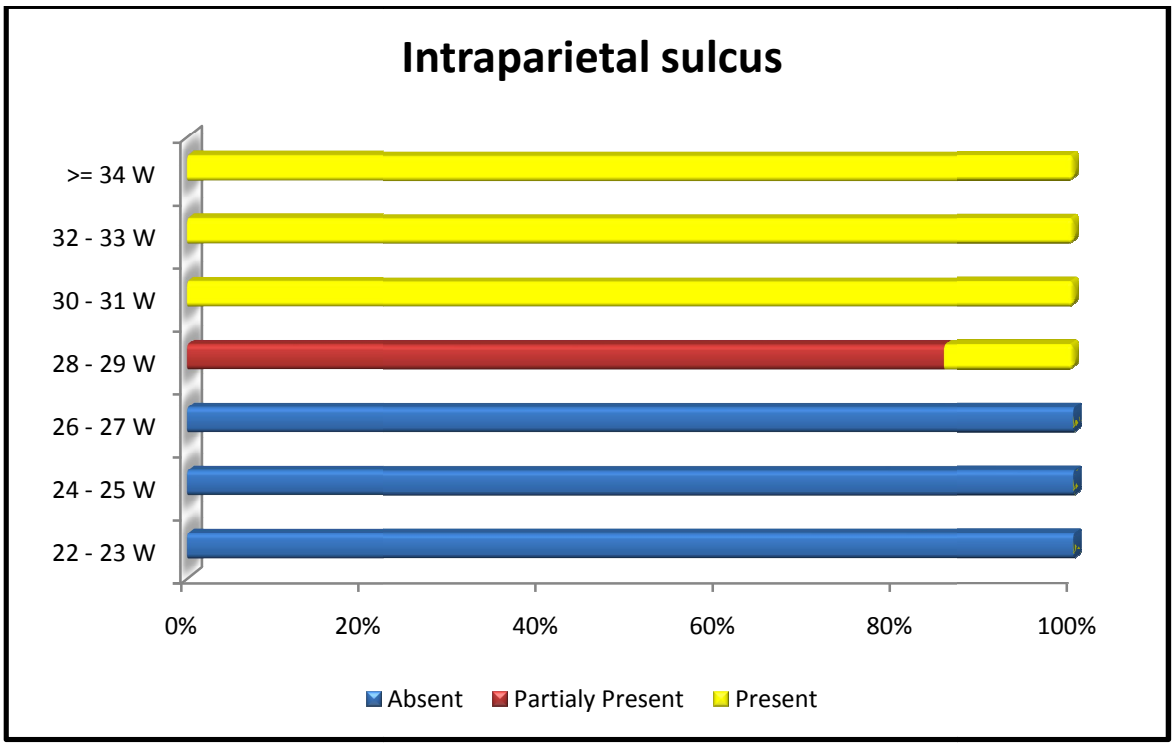


Fig 5.16 Chart shows observed sequential presence of intraparietalsulcus .

INSULAR SULCI :

Insular sulci

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	46	62.2	62.2	62.2
	H	5	6.8	6.8	68.9
	P	23	31.1	31.1	100.0
	Total	74	100.0	100.0	

Table 5.37 shows frequency table of insular sulcus .

Crosstab						
			Insular sulci			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	23.9%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	23.9%	0.0%	0.0%	14.9%
	26 - 27 W	Count	8	0	0	8
		%	17.4%	0.0%	0.0%	10.8%
	28 - 29 W	Count	10	0	0	10
		%	21.7%	0.0%	0.0%	13.5%
	30 - 31 W	Count	6	3	1	10
		%	13.0%	60.0%	4.3%	13.5%
	32 - 33 W	Count	0	2	8	10
		%	0.0%	40.0%	34.8%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	60.9%	18.9%
Total		Count	46	5	23	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5. 38 shows comparison of gestational age and insular sulcus .

. 15 cells (71.4%) have expected count less than 5. The minimum expected count is .54.

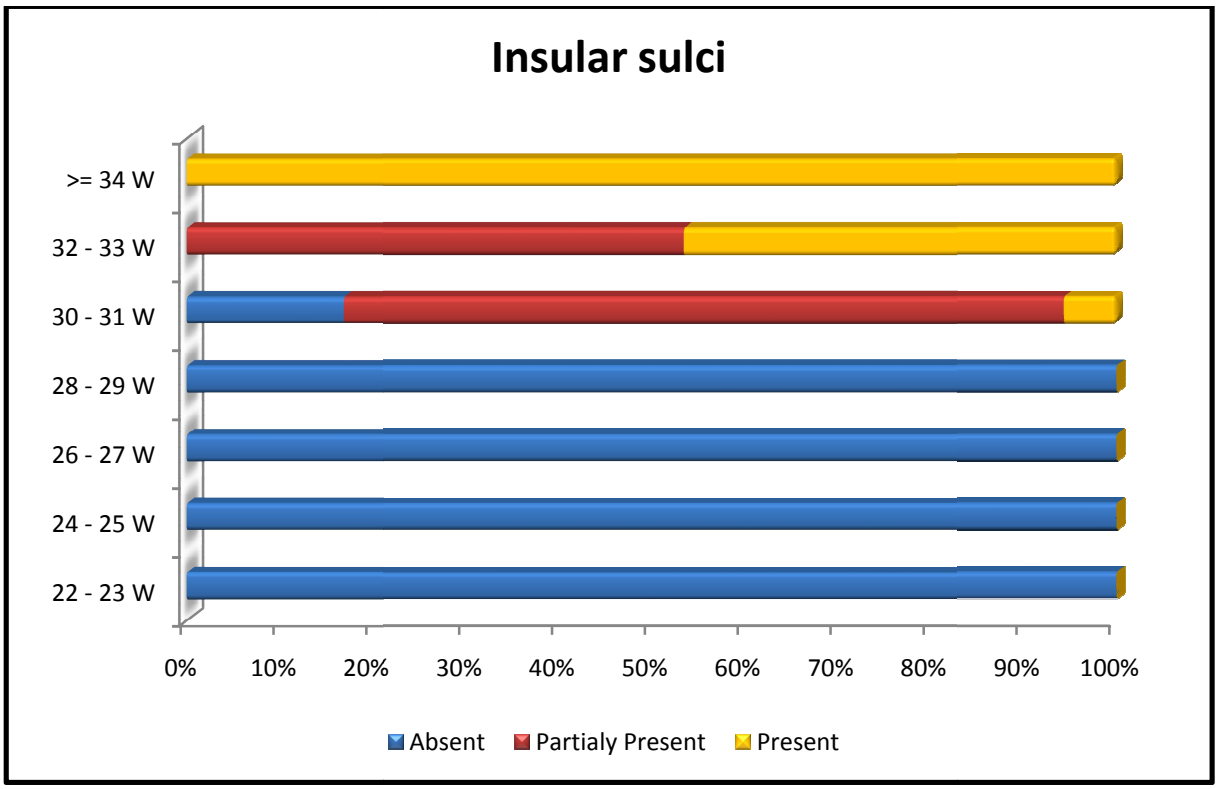


Fig 5.17 Chart shows observed sequential presence of insular sulcus .
(Statistically highly significant)

The comparison between Gestational age and presence and absence of insular sulcus shows statistically significant value of $P = 0.0005 < 0.01$.

CENTRAL SULCUS :

Central sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	25	33.8	33.8	33.8
	H	1	1.4	1.4	35.1
	P	48	64.9	64.9	100.0
	Total	74	100.0	100.0	

Table 5.39 shows frequency table of central sulcus .

Crosstab						
			Central sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	44.0%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	44.0%	0.0%	0.0%	14.9%
	26 - 27 W	Count	3	1	4	8
		%	12.0%	100.0%	8.3%	10.8%
	28 - 29 W	Count	0	0	10	10
		%	0.0%	0.0%	20.8%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	20.8%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	20.8%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	29.2%	18.9%
Total		Count	25	1	48	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.40 shows comparison of gestational age and central sulcus .

14 cells (66.7%) have expected count less than 5. The minimum expected count

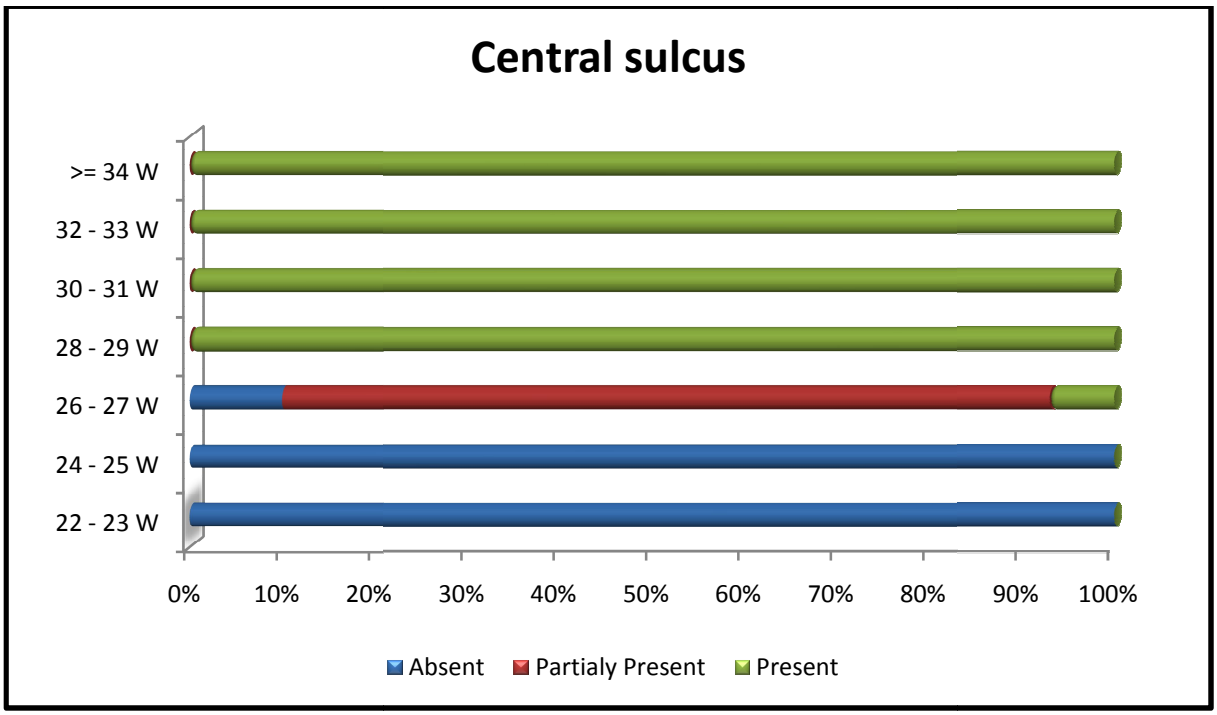


Fig 5.18 Chart shows observed sequential presence of central sulcus . (Statistically highly significant).

The comparison between Gestational age and presence of central sulcus shows significant P value of $0.0005 < 0.01$.

PRECENTRAL SULCUS :

Precentral sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	25	33.8	33.8	33.8
	H	2	2.7	2.7	36.5
	P	47	63.5	63.5	100.0
	Total	74	100.0	100.0	

Table 5.41 shows frequency table of precentral sulcus .

Crosstab						
			Precentral sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	44.0%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	44.0%	0.0%	0.0%	14.9%
	26 - 27 W	Count	3	2	3	8
		%	12.0%	100.0%	6.4%	10.8%
	28 - 29 W	Count	0	0	10	10
		%	0.0%	0.0%	21.3%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	21.3%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	21.3%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	29.8%	18.9%
Total		Count	25	2	47	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.43shows comparison of gestational age and precentral sulcus .

14 cells (66.7%) have expected count less than 5. The minimum expected count is .22.

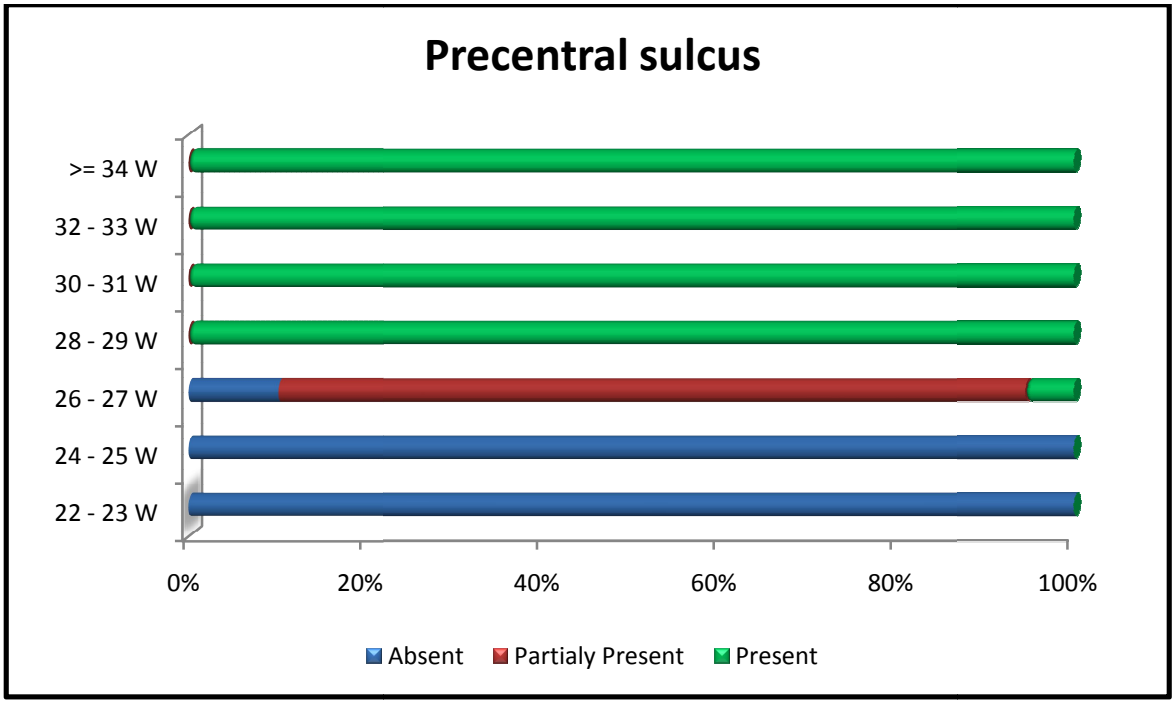


Fig 5.19 Chart shows observed sequential presence of precentral sulcus . (Statistically highly significant).

The comparison between Gestational age and presence of precentral sulcus shows significant P value of $0.0005 < 0.01$.

POSTCENTRAL SULCUS :

Postcentral sulcus

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	30	40.5	40.5	40.5
	H	8	10.8	10.8	51.4
	P	36	48.6	48.6	100.0
	Total	74	100.0	100.0	

Table 5.44 shows frequency table of post central sulcus .

Crosstab

			Postcentral sulcus			Total
			A	H	P	
GA	22 - 23 W	Count	11	0	0	11
		%	36.7%	0.0%	0.0%	14.9%
	24 - 25 W	Count	11	0	0	11
		%	36.7%	0.0%	0.0%	14.9%
	26 - 27 W	Count	8	0	0	8
		%	26.7%	0.0%	0.0%	10.8%
	28 - 29 W	Count	0	8	2	10
		%	0.0%	100.0%	5.6%	13.5%
	30 - 31 W	Count	0	0	10	10
		%	0.0%	0.0%	27.8%	13.5%
	32 - 33 W	Count	0	0	10	10
		%	0.0%	0.0%	27.8%	13.5%
	>= 34 W	Count	0	0	14	14
		%	0.0%	0.0%	38.9%	18.9%
Total		Count	30	8	36	74
		%	100.0%	100.0%	100.0%	100.0%

Table 5.45 shows comparison of gestational age and post central sulcus .

17 cells (81.0%) have expected count less than 5. The minimum expected count is .86.

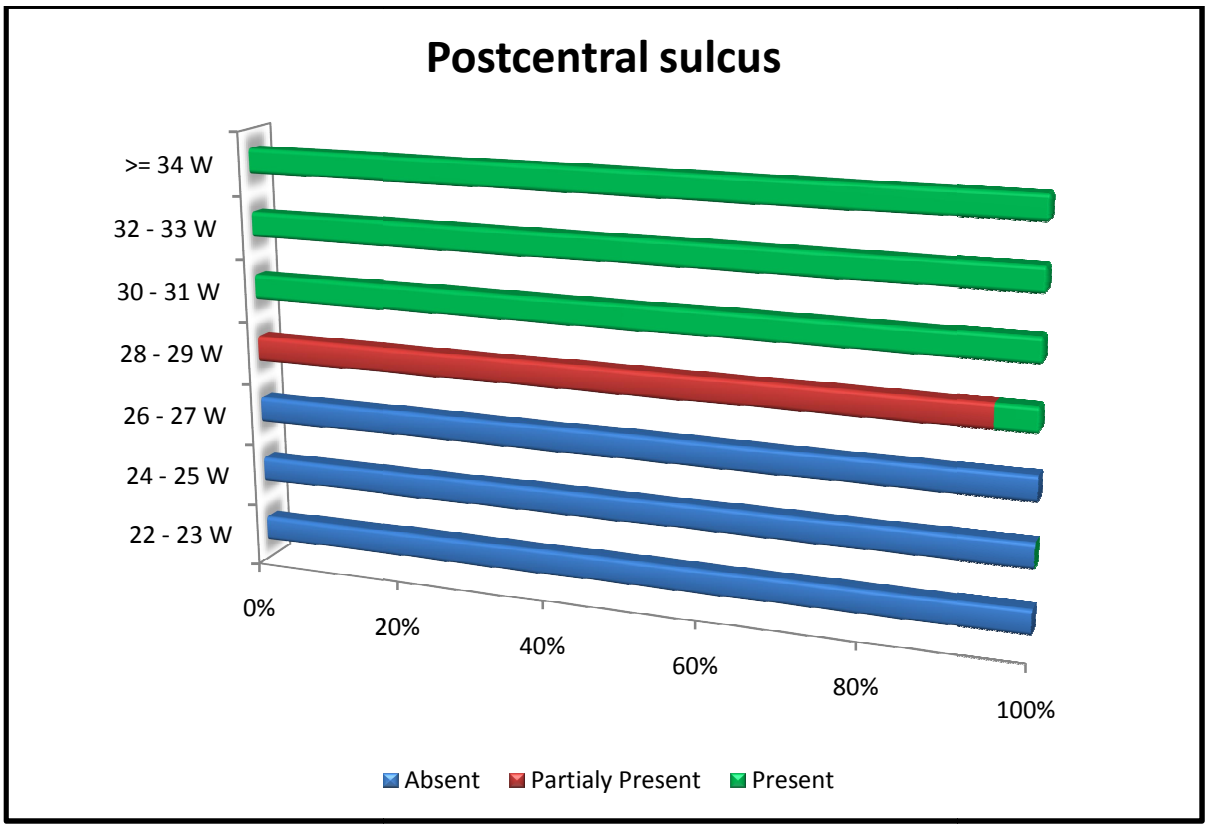


Fig 5.20 Chart shows observed sequential presence of post central sulcus . (Statistically highly significant).

The comparison between Gestational age and presence of post and absence of postcentral sulcus shows significant P value of $0.0005 < 0.01$.

RESULTS :

For the sake of statistical analysis , different gestational ages are grouped in to sequential 7 groups each comprising of contiguous 2 weeks of gestational age without overlapping (i.e 22-23 wks , 24 -25 wks etc ...). All the sequential groups comprising of different gestational age are compared with presence and absence of each described sulcus and is showing a statistically significant value ($p < 0.01$) with respect to all sulci except with parietooocipital fissure .

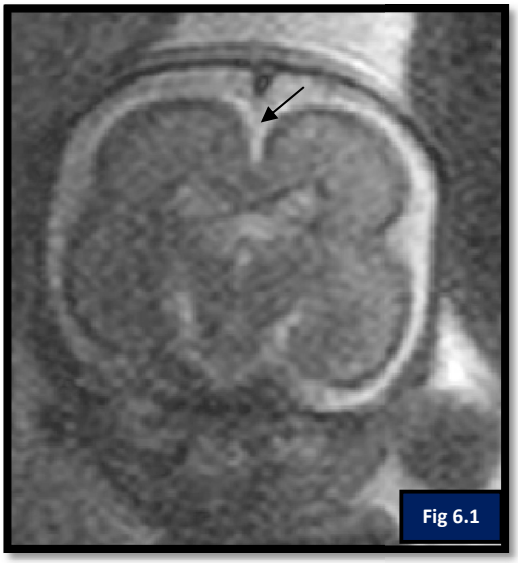
Based on the percentage analysis of the categorical variables , the cingular and calcarine sulcus are earlier detectable in 24-25 wks of gestational age whereas it is always (100%) present in 28-29 wks of gestational age . In the group of 26 – 27 wks of gestation , marginal sulcus ,collateral sulcus ,central sulcus ,precentral sulcus and superior temporal sulcus (posterior part) becomes detectable . However except collateral sulcus all others like marginal sulcus ,central sulcus ,precentral sulcus and superior temporal sulcus (posterior part) are 100 % visualised in 28-29 weeks of gestation . Collateral sulcus becomes visualised in 100 % of foetuses in 30-31 wks of gestation only .

Intraparietal , post central ,superior frontal , inferior frontal ,superior temporal (anterior part) and occipitotemporal sulci are earlier detectable in 28-29 weeks of gestation in which intraparietal , post central and superior frontal sulci are 100 % visualised in 30-31 weeks of gestation. Anterior part of superior temporal sulcus and occipitotemporal sulcus are always (100%) present in 34 weeks of gestation .Inferior frontal sulcus is always by any means present by 32-33 wks of gestation.

In the gestational age of 30-31 wks, secondary cingular sulcus, inferior temporal sulcus and insular sulcus become visible whereas 100 % of foetuses demonstrated secondary cingular sulcus by 32-33 wks of gestation , demonstrated inferior temporal sulcus by 35 weeks , and demonstrated insular sulcus by 34 weeks. Secondary occipital sulci appear to be earliest visualised by 32-33 weeks of gestation and should be seen by 35 weeks of gestation.

Interhemispheric fissure , callosal sulcus , hippocampic fissure were already always noted in all 74 fetuses starting from 22 weeks of gestation .Parietooocipital fissure also noted in 10 out of 11 fetuses by 22- 23 weeks of gestation and is doubtfully detectable in one of those foetuses . However the earliest detectable gestational age of all the above mentioned sulci could not be covered upon by the study group .

VI .ILLUSTRATIVE CASES



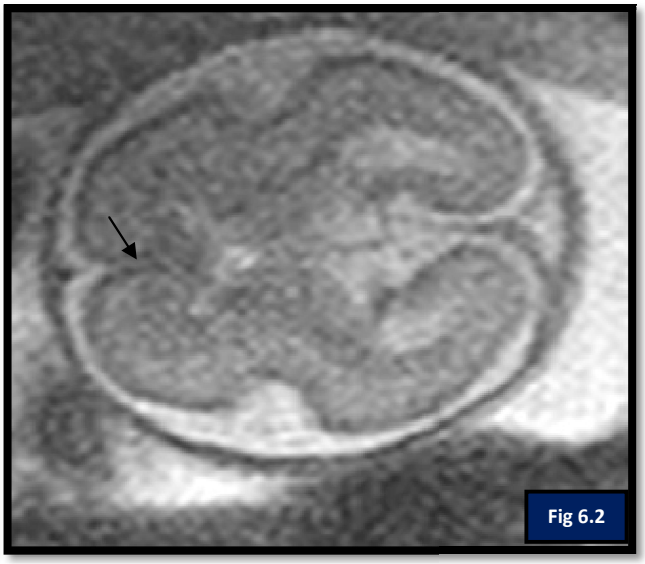


*Fig 6.1,6.2 shows interhemispheric fissure (↘) in coronal and axial sections respectively .It comes under **STAGE 1**(22-23 wks of gestation)*

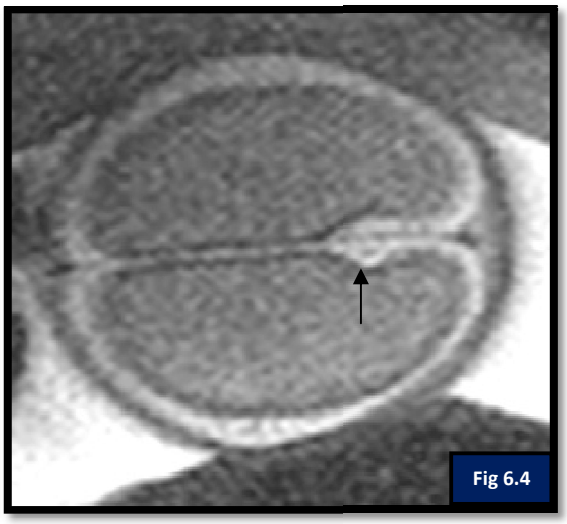


*Fig 6.3 ,6.4 shows parieto-occipital fissure (↖) in sagittal and coronal section .It happens to be in **STAGE 1** (22-23 wks of gestation)*

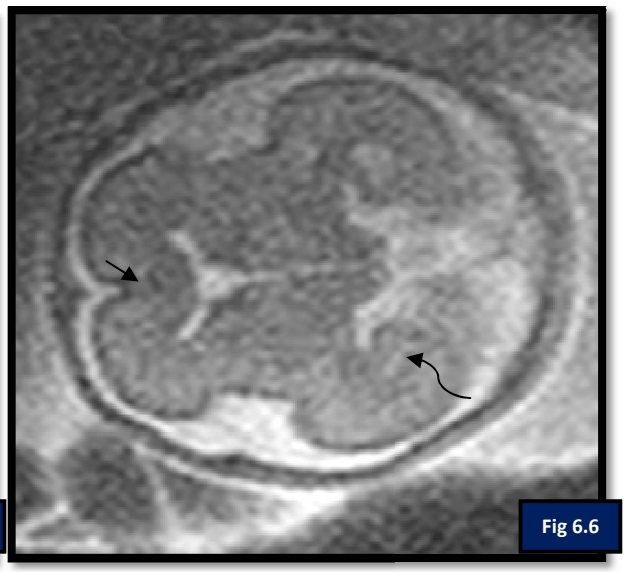
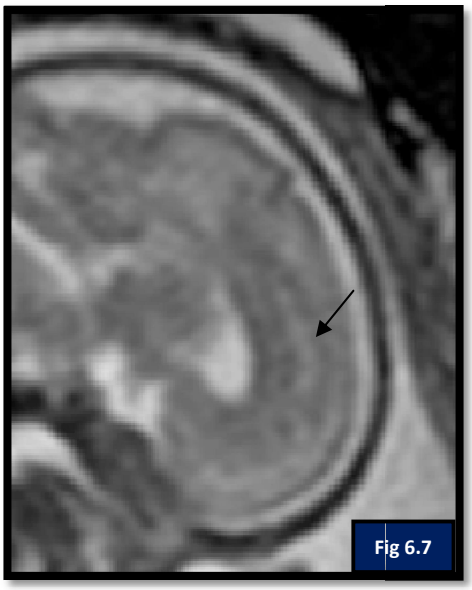


Fig 6.5 ,6.6 shows hippocampic fissure (↷) and interhemispheric fissure (↘)in coronal and axial sections ***.(STAGE 1)***



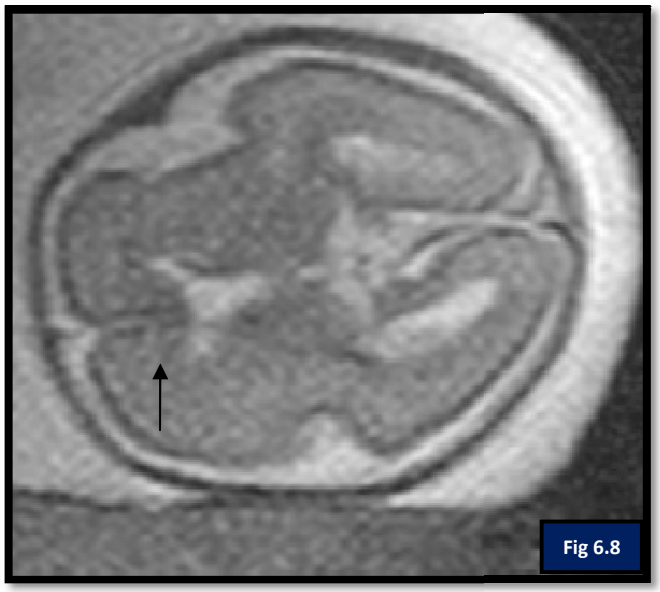
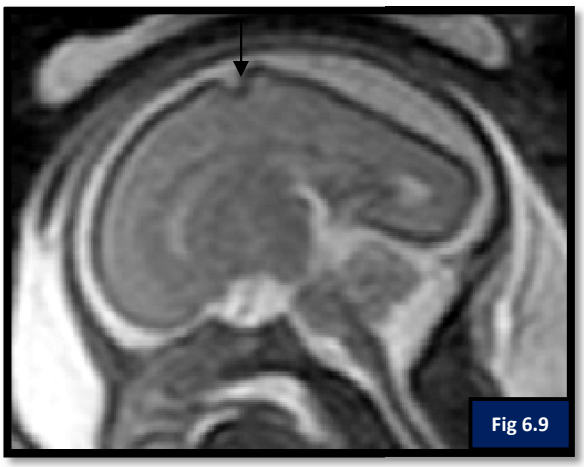


Fig 6.7 ,6.8 shows cingular sulcus (↙) in its sagittal and axial sections which usually starts seen after 24-25 weeks ***(STAGE 2)***



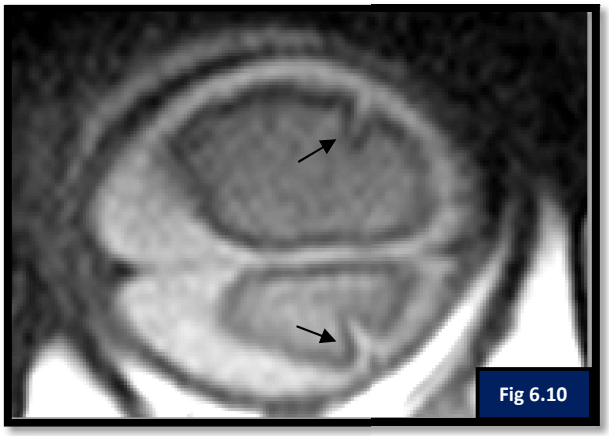
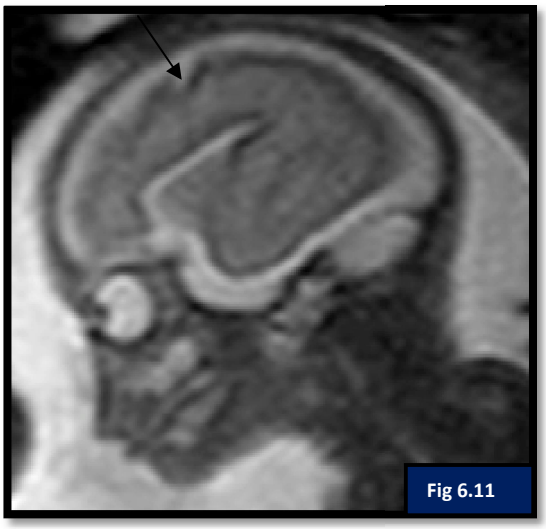
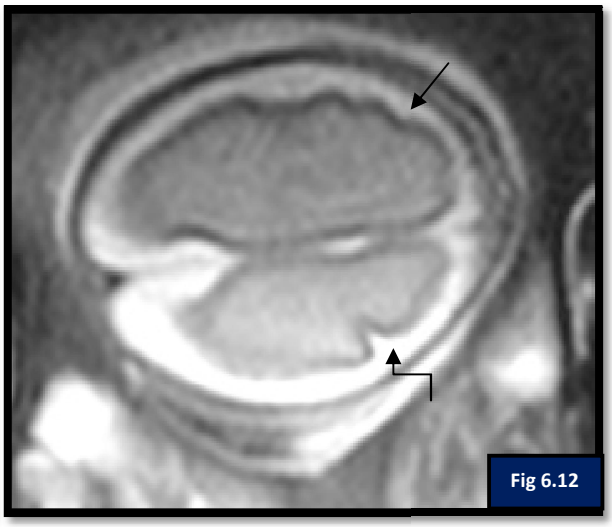


Fig 6.9 ,6.10 shows central sulcus (↘) in sagittal and axial section of brain in 26-27 weeks of gestation ***(STAGE 3)***





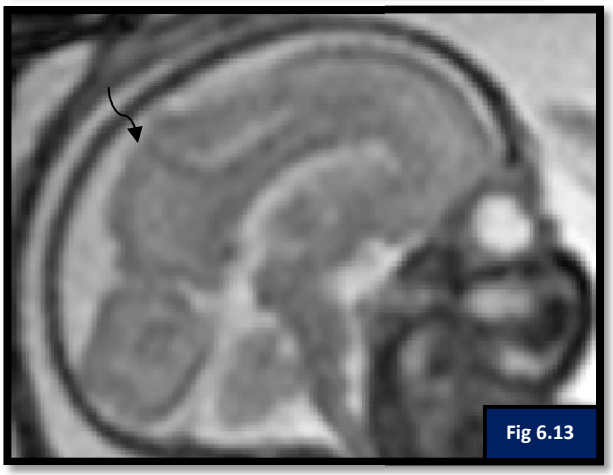
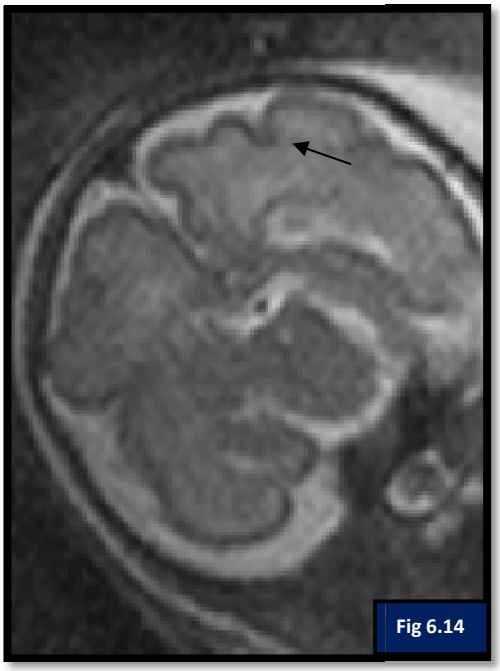
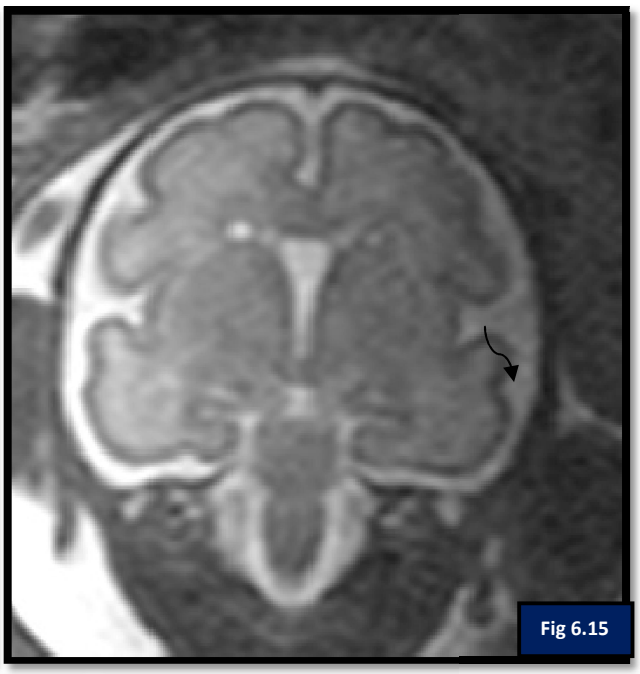
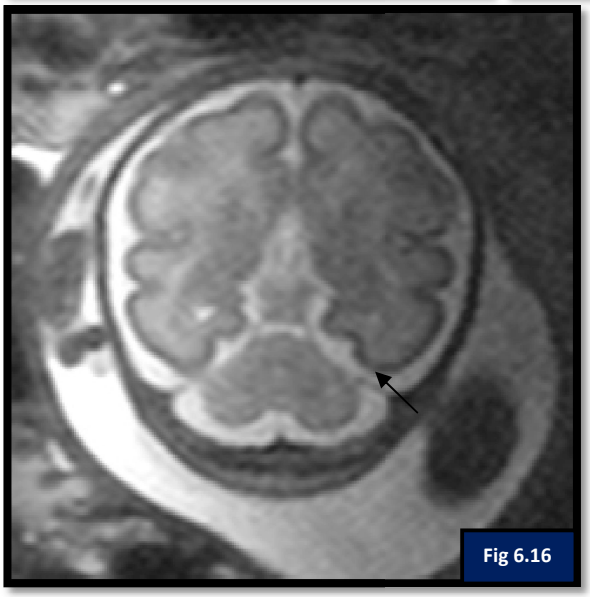


Fig 6.11 ,6.12 shows ***STAGE 3*** *sulcal development where precentral sulcus(↙) , centralsulcus (↳) can be seen. Fig .6.13 shows marginal sulcus (↘)*







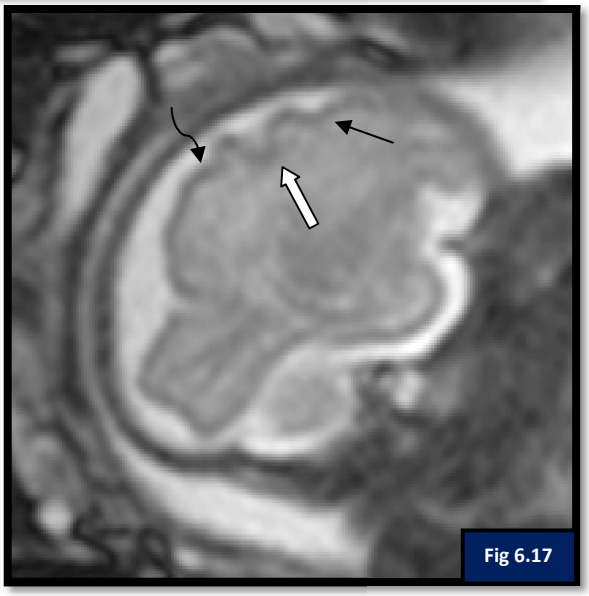


Fig 6.14 shows intraparietalsulcus , 6.15 shows superior temporal sulcus (posterior part) , 6.16 shows occipito temporal sulcus . Fig 6.17 shows partially developed post central sulcus( )with central ( )and precentral ( ) sulcus presence . All of these subjects are in ***STAGE 4*** *sulcal development .*

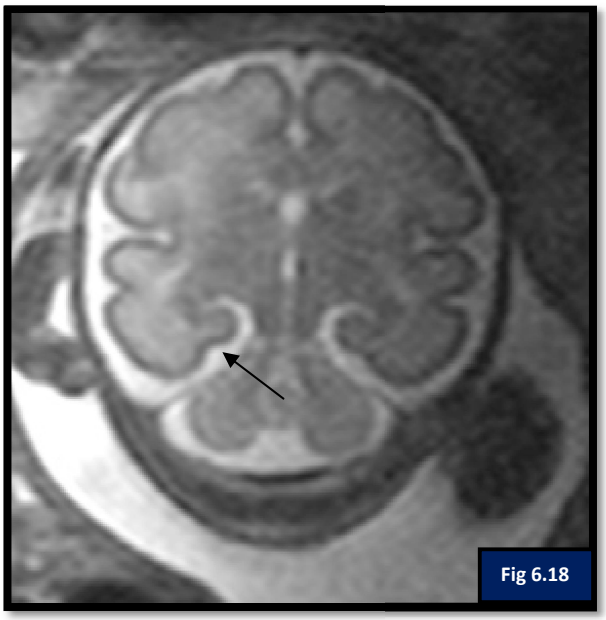
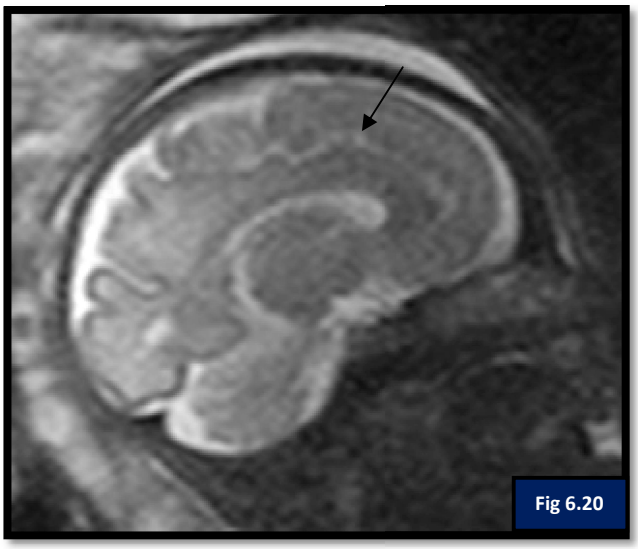


Fig 6.18 shows occipito temporal sulcus on right side and 6.16 shows superior and inferior frontal sulci clearly on right side ***(STAGE 4)***



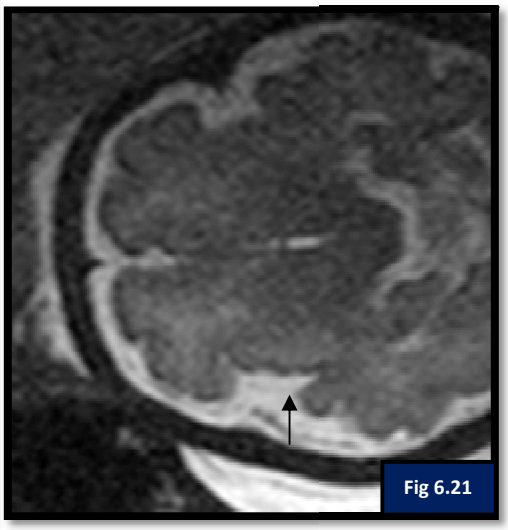


Fig 6.20 shows secondary cingular sulci with undulations.6.21 shows insular sulci . Note the undulations formed in the sylvian fissure which is termed as insular sulci ***(STAGE 5)***

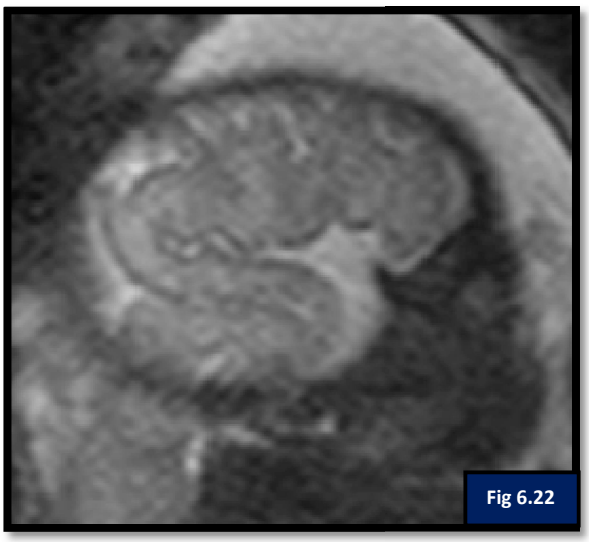


Fig 6.22

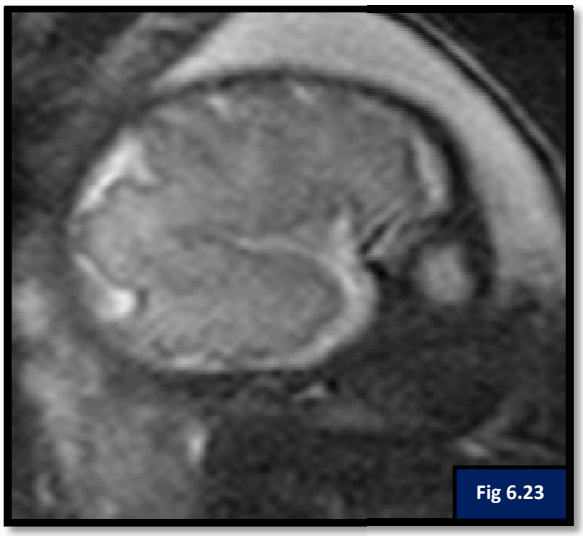


Fig 6.23

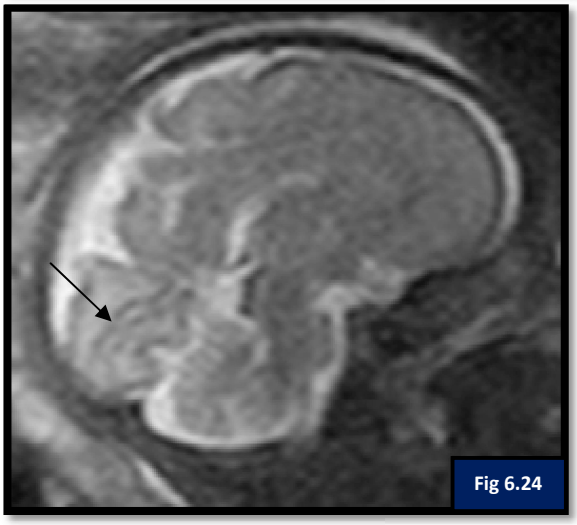


Fig 6.24

Fig 6.22 ,23,shows preogessiveopercularisation in sagittal sections ,which is significantly taking place in **STAGE 5** developmental weeks .6.24 shows well formed calcarine fissure .

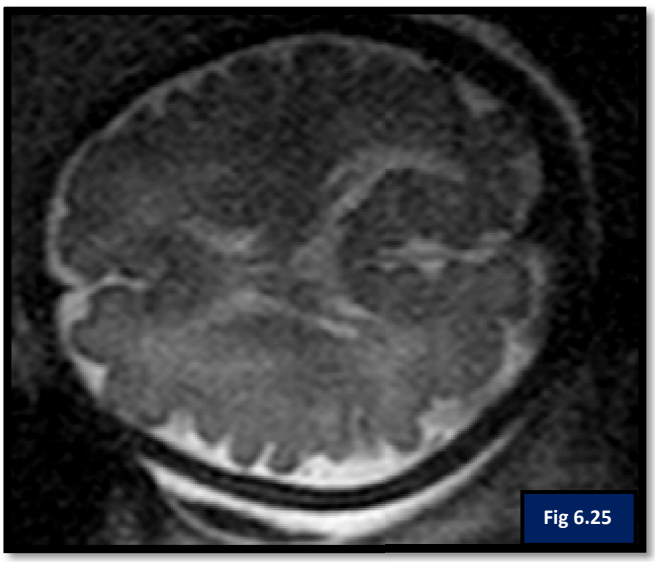


Fig 6.25


Fig 6.26

Fig 6.25 shows partially developed secondary occipital sulci ***(STAGE 6)****whereas 6.26 shows well formed secondary occipital sulci*


Fig 6.27

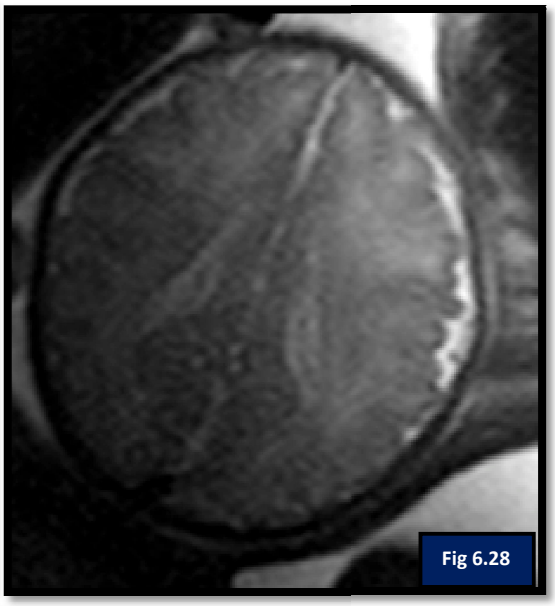


Fig 6.28

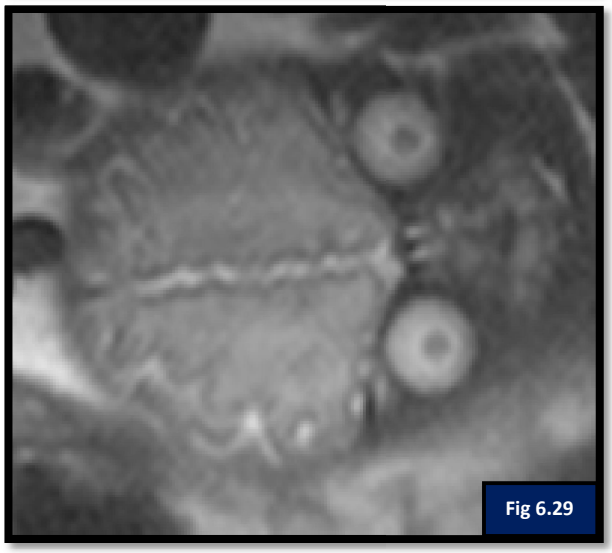


Fig 6.29

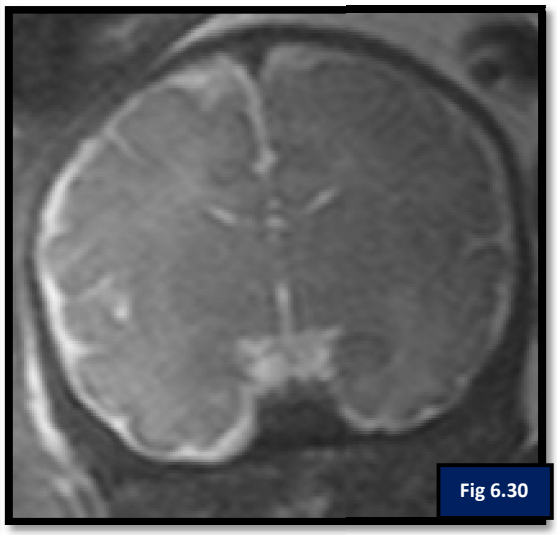


Fig 6.30

Fig 6.27,28,29,30 shows multiple level sections of brain in various axes which closely resembles well matured brain of an adult .since after 34 weeks it becomes difficult to segregate the different sulci in foetal MRI due to scarcity of intersulcal CSF filled space .Hence it is not included in the stages .

VII .DISCUSSION

VII. DISCUSSION

MRI is now being increasingly used to evaluate the fetal brain and its development , particularly when a fetus is at high risk for neurodevelopmental disorders or when an abnormality is doubted on prenatal ultrasonogram . Since 1980 , many of the studies consistently say that antenatal MRI can be used to detect abnormalities especially neuroanatomical abnormalities which are not apparently visualised by sonography.

Moreover, the identification of these abnormalities by fetal MRI can really influence the decisions made in pregnancy management and further delivery. However to say something abnormal ,it is important to know how normally things look or behave . Hence it is necessary to have some familiarity with the magnetic resonance (MR) imaging appearances of the fetal cerebral cortex at various stages of gestation for the early detection of abnormal sulcal development (42). Eventhough ultasonogram acts as a first , most available modality for examination of fetus and its brain some of its prior said limitations due to technical issues the possibility of developmental evaluation of gyral and sulcal development falls in to the hands of fetal MR technique especially during the second and third trimesters.

As said by Barkovich *et al*., 1988 (43); O'rahilly and Muller, 2001 (44) , the progression of myelination and gyral and sulcal formation are the indicators of functional maturity in the fetal brain and it can also well be correlated with psychomotor development. Hence to evaluate fetal brain maturation either

myelinaton or sulcal development can be followed up in images ,but however myelination occurs only partially in the inuterofetus, starting from the thalamus and brain stem (Yakovlev and Lecours, 1967 (45); Lee *et al*., 1986 (46)).

STAGES	GA	SULCI
STAGE 1	**22-23 WKS**	i. Interhemispheric fissure, hippocampicfissure ,callosal sulcus , parietooccipital fissure may be present .
STAGE 2	**24-25 WKS**	i. Calcarine and cingular sulcus may be present . ii. Stage 1 sulci must be present .
STAGE 3	**26-27 WKS**	i. Marginal ,collateral,central ,precentral ,superior temporal (posterior part) sulci may be present ii. Stage 1 ,2 sulci must be present .
STAGE 4	**28-29 WKS**	i. Intraparietal , post central ,superior frontal ,inferior frontal ,superficial temporal (anterior) sulci may be present ii. Stage 1,2,3 sulci must be present .
STAGE 5	**30-31 WKS**	i. Secondary cingular ,inferior temporal and insular sulci may be present . ii. Stage 1,2,3,4 sulci must be present
STAGE 6	**32-33 WKS**	i. Secondary Occipital Sulci may be present . ii. Stage 1,2,3,4,5 sulci must be present .

Table7.1 shows proposed stages of sulcus development .

Thus, sulcal development is considered to be more accurate indicator of fetal brain maturation inutero than myelination. As the gestational age advances the sequential

development of sulcation also progresses. Hence we attempted to stage the development of sulcation based on the serial appearance of particular sulci in MR images (Table 7.1) .

The above said stages are mainly based on the fact that there is a sequential appearance pattern of cerebral sulci . Hence this developmental classification of sulcal formation may allow the evaluation of fetal maturation from fetal MR images in relation to GA especially during the second and third trimesters. Our classification is based on both earliest visualisation of various sulci and its deadline visibility in relation to gestational age, which makes our classification both more sensitive as well as more specific in detecting neuroanatomical abnormalities .

However our study also provides a cut off gestational age for each and every sulcus (Table7.2) to say it is abnormal, if still an sulci is not visualised beyond it , thus making our study results more specific in finding any sulcal abnormalities . Eventhough it is said to be more specific , as you can see in the table , the correlation between the sulcal development and gestational age can only be done after 28 weeks of gestational age, when the classification is solemnly based upon 100% visualisation . Hence we attempted to classify combining both earliest and deadline visibility of each sulci .

The below table shows that the assessment of sulcal formation and brain maturation can be done most accurately through fetal MRI after 28 weeks of gestation , which appears to be reiterating the MRI findings of Garel et al .

SULCI	EARLIEST DETECTABLE	ALWAYS PRESENT(100%)
CINGULAR SULCUS	24-25 WKS	28-29 WKS
SECONDARY CINGULAR SULCUS	30-31 WKS	32-33 WKS
MARGINAL SULCUS	26-27 WKS	28-29 WKS
CALCARINE SULCUS	24-25 WKS	28-29 WKS
SECONDARY OCCIPITAL	32-33 WKS	35 WKS
COLLATERAL SULCUS	26-27 WKS	30-31 WKS
OCCIPITOTEMPORAL	28-29 WKS	34 WKS
SUPERIOR FRONTAL	28-29 WKS	30-31 WKS
INFERIOR FRONTAL	28-29 WKS	32-33 WKS
SUPERIOR TEMPORAL (POSTERIOR)	26-27 WKS	28-29 WKS
SUPERIOR TEMPORAL (ANTERIOR)	28-29 WKS	34 WKS
INFERIOR TEMPORAL SULCUS	30-31 WKS	35 WKS
INTRAPARIETAL SULCUS	28-29 WKS	30-31 WKS
INSULAR SULCI	30-31 WKS	34 WKS
CENTRAL SULCUS	26-27 WKS	28-29 WKS
PRECENTRAL SULCUS	26-27 WKS	28-29 WKS
POSTCENTRAL SULCUS	28-29 WKS	30-31 WKS

Table 7.2 shows gestational age groups in which sulci may present at its earliest and can be always be visualised .

Mcardle *et al*. (1987) (47), using MR - T1 images, anatomically classified the cortex development in preterm infants which comprises of five groups . They are as follows

Gw1: Smooth cortex without convolutions .Hypointense whitematter with thin smooth cortex.

Gw2: Cortex shows loose infolds with visible CSF space in between , deeper in occipital lobes than the frontal lobes .

GW 3: Sulcal folds becomes more tightly packed , to obliterate the CSF space in the sulci . All these changes first appear in the parietooccipital region.

GW 4: The cortex becomes deeply infolded and isolates in to discrete patches along with white matter in the frontal and occipital areas segregated by folds of the insular cortex.

GW 5: The cortex becomes extensively and compactly infolded , especially in the parietooccipital region. Whereas Occipital patches of white matter are not well seen as the sulci encroaches .

These stages appears to be more nonspecific when compared to our classification . It was based on gray–white matter differentiation , and it was also determined how post conceptional age was related to the development of sulcal formation . As per Garel et al , sulcus formation are best evaluated during the gestational period of 28 to 34 weeks but Mcardle *et al*. categorized this whole period into a single stage . Moreover , the duration of each stage was huge and it varied from 3 to 10 weeks in their classification. Thus, their classification cannot be considered to be too accurate. On the other hand , in our classification, the gestational period of 28 to 33 weeks was classified into 3 stages . Since beyond 34 weeks no newer sulci appear to emerge it was not considered in our classification. Apart from that unlike Mcardle's classification each stage of our classification comprises of only 2 weeks without any overlapping .

Van der Knaap *et al*. (1996) (20) reported and compared MR images of seven regions of brain on prematurely delivered infants and infants expired within one week after birth by evaluating the width of the gyrus and depth of the sulcus in reference to postconceptional age. Likewise we also attempted to classify our foetuses into their gyration stage. However, their results appears to be 2 to 4 weeks later than ours for each gyration stage. The possible major difference between their observed stages and ours is that their study was an evaluation of preterm infants and infants who died within one week of delivery, while ours comprises of normal foetuses and are expected to be delivered at term. Therefore, To estimate the sulcal formation using fetal MR images, we feel that our classification may be more appropriate. We found it be still more helpful in second and third trimester when usually antenatal MRI are done if at all for other indications .

Only a few investigators have attempted to study the fetal MR images of sulcal and gyralformation . In that the first ones were Levine and Barnes (1999) who reported the developmental pattern of sulcal formation in relation to gestational age on MR images. However, their findings may not be considered useful for the assessment of brain maturation, because in their study, most of the subjects undergone MRI for maternal indications and fetal non neurological indications. Hence ,the image slices were not obtained in the orthogonal plane to the brain in all cases. But in our study, all the cases imaged specifically for foetal brain following a standard protocol for brain and also cases in which images were not obtainable in the orthogonal plane to brain were excluded from analysis. In addition, they included twin gestation mothers in whom a delay of two to three weeks in the development of

gyral and sulcal formation occurs when compared to that in a singleton which has been already reported (Chi *et al*.,1977). Whereas in our study only singleton are taken in to account .

Seiji abe et al , did their assessment on cortical gyrus and sulcus by dividing the study group in to 8 and compared the individual groups to give developmental stages of sulcal and gyral development which comprises of 8 stages .Their classification was focussed only on the frontal and temporal lobe sulcal formation leaving behind the stages of development of sulci in parietal and occipital lobes . Hence we feel that our classification is more reliable and accurate than theirs in assessing the brain maturation in terms of sulcation in toto .

On retrospective correlation (Table 7.3) with prior antenatal MR study on normal cerebral sulcation done by Garel et al , our study appears to be well correlated with their respective gestational age of presence of particular sulci except for few sulci namely secondary cingular sulci , secondary occipital sulci , occipitotemporal sulci ,, superior temporal sulcus (anterior part) , inferior temporal sulcus and insular sulcus .All these above said sulci appear to be present earlier by 1 or 2 weeks when compared to presence of sulci described by Garel et al . And also according to Garel all the primary sulci appears before 34 weeks, whereas in our study all the primary sulci tends to be present even before 32- 33weeks gestation. This may be attributed to the usage of 1.5 T MRI in our study and Garel et al were able to perform prenatal MR imaging only using 0.5 T magnetic field.

SULCI	NP (WKS) APPEARANCE (Chi et al)	GAREL ET AL (WKS)	LAN ET AL (WKS)	GIRARD ET AL (WKS)	OUR STUDY
IHS	10	22-23			AP
CAL	14	22-23			AP
POF	16	22-23	26	20	AP
HF		22-23			AP
CIN	18	24-25		27	24-25 WKS
SCS	32	33			30-31 WKS
MS		27			26-27 WKS
CLC	16	24-25		24	24-25 WKS
SOS	34	34			32-33 WKS
COL	23	27			26-27 WKS
OTS	30	33			28-29 WKS
SFS	25	29			28-29 WKS
IFS	28	29			28-29 WKS
STS-P	23	27	24-26	28	26-27 WKS
STS-A	-	32			28-29 WKS
ITS	30	33			30-31 WKS
IPS	26	28			28-29 WKS
IS	34-35	34			30-31 WKS
CS	20	27	24-26	24	26-27 WKS
PRE CS	24	27	24-26	24	26-27 WKS
POST CS	25	28	24-26	24	28-29 WKS

Table 7.3 correlated findings of our study with neuraopathological appearance and garel et al other studies using MRI .(AP – already present)

(IHS - *Interhemispheric Fissure ,CAL- callosal sulcus ,POF - parietooccipital sulcus,HF - hippocampic fissure , CIN - cingular sulcus, SCS- secondary cingular sulcus,MS- marginal sulcus,CLC- calcarine sulcus, SOS - secondary occipital sulcus,COL- collateral sulcus,OTS - occipitotemporal sulcus, SFS - superior frontal sulcus,IFS - inferior frontal sulcus,STS-P - superior temporal(posterior),STS-A -superior temporal (anterior),ITS - inferior temporal sulcus,IPS- Intraparietal sulcus,IS- insular sulci,CS- central sulcus ,PRE CS-precentral sulcus,POST CS-postcentral sulcus)*

Cortical sulcation was considered to be a appropriate and good marker of fetal brain maturation by neuropathologists(48,49,4); however, even among these neuropathologic researchers , there were some sort of discrepancies prevailed concerning the time of appearance of cerebral sulci . According to Larroche (49), the superior temporal sulcus was considered to be good morphologic criteria of gestational age and it was described to appear at 28 weeks gestation, whereas Chi et al (4) observed the same sulcus by 24 to 26 weeks gestation. Moreover, the central sulcus was described to be detectable by 20 weeks of gestation as per Chi et al (4) and Larroche (49) where as by 24 weeks of gestation according to Dorovini-Zis and Dolman (48). These discrepancies may be due to several factors such as 1. Difference in field strength of the MRI machines used in various studies and difference in sensitivity of sequences 2. Calculation of gestational age, which was not calculated based on the same criteria for all the author - it was calculated by last menstrual period by some authors (4, 49) (which is more unreliable), and some of them calculated by using head circumference, and crown-to-heel length measurements . 3. Sampling size (cohort size) which varied from 30 (49) to 80 (48) to 207 (4) foetuses 4. Different techniques of neuropathological examination such as gross inspection of the brain, photographs of the fixed brains , serial sections of the brain

with varying thicknesses . and 5. laterality of brain side and inclusion of twin gestation , which may influence sulcation . These discrepancies emphasize the difficulty in establishing a reliable pattern of sulcation even in the case of neuropathologists with a high degree of precision.

LIMITATIONS :

We feel that for a formation of a standards of reference of normal pattern of sulcal development ,there should be inclusion of still more large sample size in to the study. However due to ethical issues , to include the so called normal foetuses in the research study makes it difficult to gain a large sample size . The sex and side of the brain where the sulci were identified were not included in the study . However there are literature giving evidence (Chi et al) that there is no difference between the sulcal development among male and female foetus .

RECOMMENDATIONS :

The observations of our study and the stages of the sulcal development derived from it can be made in to a chart and can easily be monitored to evaluate brain maturation of foetuses. Eventhough ,it is a MRI study ,the normal observations made in our study can very well be followed up in ultrasonagram provided acoustic window is favourable to an experienced and eminent radiologist . And we also recommend further studies based on this nomogram in early search of brain formation anomalies.

VIII.CONCLUSION

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Foetal MRI is indeed a potential screening tool in the second and third trimester fetuses who are at risk for brain anomalies. Accurate interpretation of the fetal MRI in case of some inutero brain syndromes can provide valuable information in detection of the abnormality and assessing its severity to finally make the management decisions and genetic counselling and sometimes guides therapy . Eventhough ultrasound has been a most available and useful screening tool in antenatal mothers to detect any foetal abnormalities especially in first and early second trimester , foetal brain evaluation using ultrasound still remains to be unsatisfied in late second and third trimester . By that way foetal MRI scores over ultrasound in number of conditions since it has a higher contrast resolution, which is not affected by the shadowing from the calvarium or by low amniotic fluid volume, and can be easily performed using commercially available ultrafast T2-w sequences within few seconds per sequence.

This study provides an excellent timetable of the appearance of sulci with sequential stages of development of them with respect to gestational age using foetal MRI which would add a cherry on top in the utilities of foetal MRI . This kind of evaluation of the developmental stages of sulcal formation using fetal MR images tends to allow the evaluation of fetal maturation in relation to gestational age during the second and third trimesters Because the fetal brain is a dynamic structure, it is important for radiologists to get familiarize with the normal appearance of the fetal brain at different gestational ages in order to identify and characterize abnormalities of

foetal brain better . The absence or abnormal appearance of a particular sulcus at the appropriate fetal age should raise suspicion about the possibility of abnormal or delayed cortical development (42).

Our classification may also be useful for prenatal detection of abnormal sulcal formation which may be associated with cerebral palsy (Naeye *et al*., 1989) (50). Hence if this prenatal detection can be done, it may be possible to give appropriate care to the foetus to avoid difficulties during delivery. The use of our classification may also lead to the early detection of focal lesions in the brain. Since postnatal sulcal and gyral formation is very much accelerated in children, the complicated gyral structure may sometimes mask focal lesions (Furusho *et al*., 1998) (51) after birth ,the prenatal detection of fetal anomalies can really contribute to improvement in their quality of life. Such diagnosis may also be cost-effective. Hence our stages of the sulcal development patterns should be made in to use for the evaluation of brain maturation and early detection of gyral and sulcal formation anomalies .

IX.BIBLIOGRAPHY

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IX.ANNEXURES

MASTER CHART

S.N	NAME	AGE	MAR	CON	OBS	GA WKS	MEDIAL SURFACE								VENTRAL SURFACE			LATERAL SURFACE								
							IHS	CAL	POF	CIN	SOS	MS	CLC	SOS	HF	COL	OTS	SFS	IFS	STSP	STSA	ITS	IPS	IS	CS	PCS	POCS
1	ROSEMARY	20	19	NC	PRIMI	24	P	P	P	H	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
2	REVATHY	22	20	NC	G2P1L1	24	P	P	P	H	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
3	BHAVANI	22	20	NC	G2P1L1	23	P	P	P	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
4	MEENA	26	25	NC	PRIMI	33	P	P	P	P	P	P	P	H	P	P	P	P	P	P	P	H	P	P	P	P	P
5	VENILLA	20	18	NC	PRIMI	34	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
6	MANILA	22	18	C	G2P2L1	31	P	P	P	P	P	P	P	A	P	P	H	P	P	P	H	H	P	H	P	P	P
7	MANIKACVALLI	28	23	NC	G2P1L1	36	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
8	ARUNA MUTHUKUMAR	26	24	NC	G3P1L1A1	26	P	P	P	H	A	A	P	A	P	A	A	A	A	A	A	A	A	A	H	H	A
9	REVATHY MANIKANDAN	26	19	C	G3P2L2	33	P	P	P	P	P	P	P	A	P	P	P	P	P	P	P	H	P	P	P	P	P
10	CHITRA	32	28	NC	PRIMI	33	P	P	P	P	P	P	P	A	P	P	P	P	P	P	P	H	P	P	P	P	P
11	SIVASAKTHI	26	24	NC	G2P1L0	34	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
12	LAVANYA	21	18	NC	PRIMI	29	P	P	P	P	A	P	P	A	P	P	H	P	P	P	A	A	P	A	P	P	H
13	MUNIRA	26	22	NC	G3P2L2	28	P	P	P	P	A	P	P	A	P	H	A	H	H	P	H	A	H	A	P	P	H
14	MYTHILI	20	18	NC	PRIMI	30	P	P	P	P	A	P	P	A	P	P	A	P	H	P	A	A	P	A	P	P	P
15	SURAIYA	25	22	NC	G2P2L1	26	P	P	P	P	A	A	H	A	P	A	A	A	A	A	A	A	A	A	A	A	A
16	KALAYARASI	26	19	NC	G3P2L2	32	P	P	P	P	P	P	P	P	P	P	P	P	P	P	H	H	P	P	P	P	P
17	PARVEEN BANU	22	19	NC	G3P2L2	28	P	P	P	P	A	P	P	A	P	H	A	H	H	P	H	A	H	A	P	P	H

18	DHANALAKSHMI	26	20	NC	G2P1L1	23	P	P	P	H	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
19	SIVARANJANI	21	19	NC	PRIMI	27	P	P	P	P	A	P	P	A	P	P	A	A	A	P	A	A	A	A	P	P	A
20	SANTHI SAMPOORNA	23	22	C	PRIMI	23	P	P	P	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
21	ESHWARIAMMA	23	20	NC	G2P1L1	30	P	P	P	P	A	P	P	A	P	P	A	P	H	P	A	A	P	A	P	P	P
22	PADMA	24	21	NC	PRIMI	26	P	P	P	P	A	A	H	A	P	A	A	A	A	A	A	A	A	A	A	A	A
23	SUGANYA	22	19	C	G2P1L1	22	P	P	H	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
24	VAIDESHWARI	22	19	NC	G2P1L1	29	P	P	P	P	A	P	P	A	P	P	H	P	P	P	A	A	P	A	P	P	H
25	ANITHA	19	18	C	PRIMI	25	P	P	P	P	A	A	P	A	P	A	A	A	A	A	A	A	A	A	A	A	A
26	POONJOLAI	20	19	NC	PRIMI	30	P	P	P	P	A	P	P	A	P	P	A	P	H	P	A	A	P	A	P	P	P
27	SHALINI	19	18	NC	G2P1L1	22	P	P	P	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
28	MANJUDEVI	23	21	NC	PRIMI	24	P	P	P	H	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
29	NARMDHA	29	23	NC	G2P1L1	29	P	P	P	P	A	P	P	A	P	P	H	P	P	P	A	A	P	A	P	P	H
30	UMA MAHESWARI	30	24	NC	G3P1L1A1	36	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
31	SUGANYA	25	22	NC	G2P1L1	33	P	P	P	P	P	P	P	H	P	P	P	P	P	P	P	P	P	H	P	P	P
32	REKHA	29	23	NC	G2P1L1	26	P	P	P	P	A	A	P	A	P	A	A	A	A	A	A	A	A	A	A	A	A
33	RAMYA	20	18	C	PRIMI	31	P	P	P	P	P	P	P	A	P	P	H	P	P	P	P	P	P	P	P	P	P
34	SUDHA	22	20	NC	PRIMI	24	P	P	P	P	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
35	SUCHITRA	21	19	NC	PRIMI	22	P	P	P	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
36	MUMTAJ	23	20	C	G2P1L1	29	P	P	P	P	A	P	P	A	P	P	H	P	P	P	A	A	P	A	P	P	H
37	GOMATHY	26	22	NC	G2P1L1	24	P	P	P	P	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
38	DEEPA	25	21	NC	PRIMI	30	P	P	P	P	A	P	P	A	P	P	A	P	H	P	A	A	P	A	P	P	P
39	MUMTAJ	20	19	NC	PRIMI	22	P	P	P	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
40	BHAVANI	23	20	NC	G2P1L1	31	P	P	P	P	P	P	P	A	P	P	H	P	P	P	P	H	P	H	P	P	P
41	SARASWATHY	29	23	NC	G3P1L1A1	25	P	P	P	P	A	A	H	A	P	A	A	A	A	A	A	A	A	A	A	A	A
42	RAMYA	28	24		G2P1L1	35	P	P	P	P	P	P	P	H	P	P	P	P	P	P	P	P	P	P	P	P	P

43	MEGRUNISHA 19.7	33	24	NC	G2P1L1	31	P	P	P	P	P	P	P	A	P	P	H	P	P	P	H	A	P	A	P	P	P
44	KUTTIMA	20	19	C	PRIMI	29	P	P	P	P	A	P	P	A	P	P	H	P	P	P	A	A	P	A	P	P	H
45	SUGANYA	22	19	NC	G2P1L1	24	P	P	P	P	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
46	KALAVATHY	24	16	C	G3P2L2	34	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	H	P	P	P	P	P
47	JOTHILAKSHMI	34	22	NC	G2P1L1	25	P	P	P	P	A	A	P	A	P	A	A	A	A	A	A	A	A	A	A	A	A
48	KAMALI	21	20	NC	G2P1L1	30	P	P	P	P	A	P	P	A	P	P	A	P	H	P	A	A	P	A	P	P	P
49	ESAKKITHAI 20.7	18	17	NC	G2P0L0A1	36	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
50	RUPAVATHY	20	18	NC	G2P1L1	28	P	P	P	P	A	P	P	A	P	P	A	A	A	P	H	A	P	A	P	P	P
51	PADMASREE	27	19	NC	G3P1L1A1	36	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
52	THIRUMANI	28	21	NC	G2P1L1	34	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
53	KAVERI	23	18	NC	G2P1L1	23	P	P	P	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
54	CHITRA	24	24	NC	PRIMI	24	P	P	P	P	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
55	GHUSIYA BEGAM	35	23	NC	G4P1L1A2	27	P	P	P	P	A	P	H	A	P	P	A	A	A	P	A	A	A	A	P	P	A
56	NISHANTHI	24	20	NC	PRIMI	33	P	P	P	P	P	P	P	A	P	P	P	P	P	P	P	P	P	H	P	P	P
57	GIRIJA	23	20	NC	G2P1L1	25	P	P	P	P	A	A	P	A	P	A	A	A	A	A	A	A	A	A	A	A	A
58	POONKODI	35	30	NC	G3P1L1A1	23	P	P	P	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A
59	NOORMA	22	21	NC	PRIMI	32	P	P	P	P	P	P	P	A	P	P	P	P	P	P	P	H	P	P	P	P	P
60	SARITHA	21	19	NC	G2P1L1	28	P	P	P	P	A	P	P	A	P	H	A	H	H	P	H	A	P	A	P	P	H
61	MALA	18	18	NC	PRIMI	35	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
62	KEERTHANA	20	16	NC	G4P1L1A2	32	P	P	P	P	P	P	P	A	P	P	H	P	P	P	A	A	P	P	P	P	P
63	SANDHIYA	24	23	NC	PRIMI	34	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	H	P	P	P	P	P
64	FATIMA	20	18	NC	G1P1L1	27	P	P	P	P	A	H	P	A	P	H	A	A	A	H	A	A	A	A	P	P	A
65	BHARATHI	39	30	NC	G2L1P1	35	P	P	P	P	P	P	P	H	P	P	P	P	P	P	P	P	P	P	P	P	P
66	MUMTAJ	20	18	NC	G2L1P1	32	P	P	P	P	P	P	P	A	P	P	P	P	P	P	H	P	P	P	P	P	P

67	UMA	29	27	NC	G2P1L1	28	P	P	P	P	A	P	P	A	P	P	A	A	A	P	H	A	H	A	P	P	P
68	KAMATCHI	32	29	NC	G2P1L1	23	P	P	P	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A	A
69	KAVITHA	24	21	NC	G2P1L1	32	P	P	P	P	P	P	P	H	P	P	H	P	P	P	P	A	P	P	P	P	P	P
70	YASHMIN	26	23	NC	G2P1L1	31	P	P	P	P	P	P	P	A	P	P	H	P	P	P	H	A	P	H	P	P	P	P
71	VASUMATHI	22	19	NC	G2P1L1	27	P	P	P	P	A	P	P	A	P	P	A	A	A	H	A	A	A	A	P	H	A	A
72	NAGAVALLI	27	25	NC	PRIMI	35	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
73	NARMADHA	22	20	NC	PRIMI	36	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
74	CHARUMATHI	23	21	C	PRIMI	23	P	P	P	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A	A	A

ii . KEY TO MASTER CHART

CATEGORIES :

A - ABSENCE OF SULCUS

P - PRESENCE OF SULCUS

H – (HALF)PARTIALLY DEVELOPED

COLUMNS

COLUMN 1 – STUDY NUMBER

COLUMN 2 – SUBJECT NAME

COLUMN 3 – AGE IN YEARS

COLUMN 4 – AGE AT THE TIME OF MARRIAGE

COLUMN 5 – CONSANGUINITY

COLUMN 6 – OBSTETRIC SCORE

COLUMN 7 – GESTATIONAL AGE AS PER FIRST TRIMESTER SCAN (LESS THAN 12 WEEKS)

SULCI ON MEDIAL SURFACE OF BRAIN :

COLUMN 8 – Interhemispheric fissure - IHS

COLUMN 9 - Callosal sulcus - CAL

COLUMN 10 - Parietooccipital fissure - POF

COLUMN 11 - Cingular sulcus - CIN

COLUMN 12 - Secondary cingular sulci - SCS

COLUMN 13 - Marginal sulcus - MS

COLUMN 14 - Calcarine fissure - CLC

COLUMN 15 - Secondary occipital sulci - SOS

SULCI ON VENTRAL SURFACE OF BRAIN :

COLUMN 16 - Hippocampic fissure - HF

COLUMN 17- Collateral sulcus - CS

COLUMN 18 - Occipitotemporal sulcus - OTS

SULCI ON SUPEROLATERAL SURFACE OF BRAIN :

COLUMN 19 - Superior frontal sulcus - SFS

COLUMN 20 - Inferior frontal sulcus - IFS

COLUMN 21- Superior temporal sulcus (posterior part) – STS P

COLUMN 22- Superior temporal sulcus (anterior part) – STS A

COLUMN 23 - Inferior temporal sulcus - ITS

COLUMN 24 - Intraparietal sulcus - IPS

COLUMN 25- Insular sulci - IS

COLUMN 26 - Central sulcus - CS

COLUMN 27 - Precentral sulcus - PCS

COLUMN 28 - Postcentral sulcus – POCS

PERFORMA

"ASSESSMENT OF NORMAL CEREBRAL SULCAL DEVELOPMENT IN FOETUS USING MRI"

NAME:	AGE/ SEX :	STUDY NO:
MARITAL HISTORY	AGE AT MARRIAGE : CONSANGUINITY :	
OBSTETRIC SCORE		
GA AS PER 12 WKS USG AN SCAN		
ASSOCIATED MATERNAL RISK FACTORS		
USG SCREENING		
MRI SCREENING		

ASSESSMENT OF SULCI	PRESENT	ABSENT	PARTIALLY DEVELOPED
Sulci of the medial cerebral surface			
Interhemispheric fissure			

Callosal sulcus			
Parietooccipital fissure			
Cingular sulcus			
Secondary cingular sulci			
Marginal sulcus			
Calcarine fissure			
Secondary occipital sulci			
Sulci of the ventral cerebral surface			
Hippocampic fissure			
Collateral sulcus			
Occipitotemporal sulcus			
Sulci of the lateral cerebral surface			
Superior frontal sulcus			
Inferior frontal sulcus			
Superior temporal sulcus (posterior part)			
Superior temporal sulcus (anterior part)			
Inferior temporal sulcus			
Intraparietal sulcus			
Insular sulci			
Sulci of the vertex			
Central sulcus			
Precentral sulcus			
Postcentral sulcus			

INFORMED CONSENT

Study title:

"ASSESSMENT OF NORMAL CEREBRAL SULCAL DEVELOPMENT IN FOETUS USING MRI "

Patient's Identification No: _____

Patient's Name: _____

Patient's Date of Birth : ___/ ___/ _____

I confirm that I have read and understood the Information sheet for the above study. I have had the opportunity to ask the questions and all my questions and doubts have been answered to my complete satisfaction.

I understand that my participation in the study is voluntary and that I am free to withdraw at any time, without giving any reason without my legal rights being affected.

I understand that clinical study personnel, the Ethics Committee and the regulatory Authorities will not need my permission to look at my health records both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw from the study. I agree to this access. However, I understand that my identity will not be revealed in any information released to third parties or published, unless as required under the law. I agree not restrict the use of any data or results that arise from this study. I agree not to withhold any information about my health from the investigator and will convey the same truthfully.

I agree to take part in the above study and to comply with the instructions given during the study and to faithfully co-operate with the study team , and to immediately inform the study staff, if I suffer from any deterioration in my health or well- being or any unexpected or unusual symptoms.

I hereby consent to participate in this study. I consent to give my medical history, undergo complete physical examination and diagnostic tests including haematological, biochemical and urine examination etc.

Signature/ Thumb Impression of the Patient : _____

Place _____ Date:_____

Patient's Name & Address : _____

_____

Signature of the Investigator: _____

Place: _____ Date: _____

Study Investigator's Name : _____

Institution: Stanley Medical College.

*Signature of the witness _____

Place : _____Date:_____

*Name and Address of the Witness :

_____

**** Mandatory for uneducated patients (where thumb impression has been provided above)***

<u>சுய ஒப்புதல் படிவம்</u>

ஆய்வு செய்யப்படும் தலைப்பு :

ஆராய்ச்சி நிலையம் :
நுண்கதிர் இயல்துறை,
தமிழ்நாடு அரசு ஸ்டான்லி மருத்துவக்கல்லூரி & மருத்துவமனை, சென்னை - 600 001.

பங்கு பெறுபவரின் பெயர் :

பங்குபெறுபவரின் எண் :

பங்கு பெறுவர் இதனை (✓) குறிக்கவும்.

மேலே குறிப்பிட்டுள்ள மருத்துவ ஆய்வின் விவரங்கள் எனக்கு விளக்கப்பட்டது. என்னுடைய சந்தேகங்களை கேட்கவும், அதற்கான தகுந்த விளக்கங்களை பெறவும் வாய்ப்பளிக்கப்பட்டது.

நான் இவ்வாய்வில் தன்னிச்சையாகதான் பங்கேற்கிறேன். எந்த காரணத்தினாலோ எந்த கட்டத்திலும் எந்த சட்ட சிக்கலுக்கும் உட்படாமல் நான் இவ்வாய்வில் இருந்து விலகி கொள்ளலாம் என்றும் அறிந்து கொண்டேன்.

இந்த ஆய்வு சம்மந்தகமாகவோ, இதை சார்ந்த மேலும் ஆய்வு மேற்கொள்ளும் போதும் இந்த ஆய்வில் பங்குபெறும் மருத்துவர் என்னுடைய மருத்துவ அறிக்கைகளை பார்ப்பதற்கு என் அனுமதி தேவையில்லை என அறிந்து கொள்கிறேன். நான் ஆய்வில் இருந்து விலகிக் கொண்டாலும் இது பொருந்தும் என அறிகிறேன்.

இந்த ஆய்வின் மூலம் கிடைக்கும் தகவல்களையும், பரிசோதனை முடிவுகளையும் மற்றும் சிகிச்சை தொடர்பான தகவல்களையும் மருத்துவர் மேற்கொள்ளும் ஆய்வில் பயன்படுத்திக்கொள்ளவும் அதை பிரசுரிக்கவும் என்

முழு மனதுடன் சம்மதிக்கிறேன்.

இந்த ஆய்வில் பங்கு கொள்ள ஒப்புக்கொள்கிறேன். எனக்கு கொடுக்கப்பட்ட அறிவுரைகளின்படி நடந்து கொள்வதுடன் இந்த ஆய்வை மேற்கொள்ளும் மருத்துவ அணிக்கு உண்மையுடன் இருப்பேன் என்றும் உறுதியளிக்கிறேன். என் உடல் நலம் பாதிக்கப்பட்டாலோ அல்லது எதிர்பாராத வழக்கத்திற்கு மாறான நோய்க்குறி தென்பட்டாலோ உடனே அதை மருத்துவ அணியிடம் தெரிவிப்பேன் என உறுதி அளிக்கிறேன்.

பங்கேற்பவரின் கையொப்பம் ..... இடம் ..... தேதி

கட்டைவிரல் ரேகை

பங்கேற்பவரின் பெயர் மற்றும் விலாசம் .....

ஆய்வாளரின் கையொப்பம் ..... இடம் ..... தேதி

ஆய்வாளரின் பெயர் .....

S.NO : **ULTRASOUND MACHINE NO :** **Form F No :**

FORM F [See Proviso to section 4(3), Rule 9(4) and Rule 10(1A)]

FORM FOR MAINTENANCE OF RECORD IN CASE OF PRENATAL DIAGNOSTIC TEST/PROCEDURE BY GENETIC CLINIC/ULTRASOUND CLINIC/IMAGING CENTRE

Section A : To be filled in for all Diagnostic Procedures/Tests

1.Name and complete address of Genetic Clinic/Ultrasound Clinic/Imaging centre: **Government Stanley medical college & hospital old washermenpet ,Chennai 600001**

2.Registration No(Under PC & PNDT ACT, 1994) : **PNA /1531/2001**

3.Patient's Name _____Age_____

4.Total Number of Living children:_____

(a) Number of Living sons with age of each living son(in years or months):

_____

(b) Number of living Daughters with age of each living daughter (in years of months):

_____

5.Husband's /wife's /Father's /Mother's Name :

_____

6.Full postal address of the patient's with Contact Number, if any_____

_____

7.(a) Referred by (Full Name and address of Doctor(s) /Genetic counselling Centre) :

_____

_____ (*Referral slips to be preserved carefully with* Form F)

(b) **Self- Referral** by Gynaecologist/Radiologist/Registered Medical Practitioner conducting the diagnostic procedures:

_____ (*Referral note with indications case papers of the patients to be preserved with*

Form F) **(Self –referral does not mean a client coming to a clinic and requesting for the test or the relatives requesting for**

the test of pregnant woman)

8. Last menstrual period /weeks of pregnancy_____

Section B : To be filled in for performing non-invasive diagnostic Procedures/ Tests only)

9.Name of the doctor performing the procedure/s:

_____

10.Indication/s for diagnosis procedure _____ *(specify with reference to the request made*

in the referral slip or in a self- referral note) (Ultrasonography parental diagnosis during pregnancy should only be performed

when indicated. The following is the representative list of indication for ultrasound during pregnancy**.(Put a "Tick against the**

appropriate indication/s for ultrasound)

i. To diagnose intra-uterine and/or ectopic pregnancy- and confirm viability

ii. Estimation of gestational age (dating).

iii. Detection of number of fetuses and their chorionicity.

iv. Suspected pregnancy with IUCD in-situ or suspected pregnancy following contraceptive failure/MTP

v. Vaginal bleeding/leaking.

vi. Follow-up of cases of abortion.

vii. Assessment of cervical canal and diameter of internal os.

viii. Discrepancy between uterine size and period of amenorrhea.

ix. Any suspected adenexal or uterine pathology/abnormality.

x. Detection of chromosomal abnormalities, fetal structural defects and other abnormalities and their follow-up.

xi. To evaluate fetal presentation and position.

xii. Assessment of liquor amniixiii.

xiii Preterm labor / preterm premature rupture of membranes.

xiv. Evaluation of placental position, thickness, grading and abnormalities (placenta praevia, retro placental hemorrhage, abnormal

adherence etc.).

xv. Evaluation of umbilical cord – presentation, insertion, nuchal encirclement, number of vessels and presence of true knot.
xvi. Evaluation of previous Caesarean Section scars.
xvii. Evaluation of fetal growth parameters, fetal weight and fetal well being.
xviii. Color flow mapping and duplex Doppler studies.
xix. Ultrasound guided procedures such as medical termination of pregnancy, external cephalic version etc. and their follow-up.
xx. Adjunct to diagnostic and therapeutic invasive interventions such as chorionic villus sampling (CVS), amniocenteses, fetal blood sampling,
fetal skin biopsy, amnio-infusion, intrauterine -infusion, placement of shunts etc.
xxi. Observation of intra-partum events.
xxii. Medical/surgical conditions complicating pregnancy.
xxiii. Research/scientific studies in recognized institutions.

11. Procedures carried out (Non-Invasive) (**Put a "Tick" on the appropriate procedure**)

i. Ultrasound *(**Important Note**: Ultrasound is not indicated/advised/performed to determine the sex of fetus except for*
diagnosis of sex-linked diseases such as Duchene Muscular Dystrophy, Hemophilia A& B etc.)

ii. Any other (specify)_____

12. Date on which declaration of pregnant woman/ person was obtained :_____

13. Date on which procedures carried out:_____

14. Result of the non-invasive procedure carried out *(report in brief of the test including ultrasound carried out)*_____
_____

15. The result of pre-natal diagnostic procedures was conveyed to
_____on_____

16. Any indication for MTP as per the abnormality detected in the diagnostic procedures/tests
_____

Date: **Name, Sign and Registration Number with Seal of the Gynaecologist**
Place: **/Radiologist /Registered Medical Practitioner performing Diagnostic Procedure/s**.

Section D:

Declaration of the person undergoing prenatal diagnostic test/ procedure

I, Mrs./Mr._____ declare that by undergoing _____ Prenatal Diagnostic Test/ Procedure. I do not want to know the sex of my foetus.

Date: **Signature/Thumb impression of the person undergoing the Prenatal**
Place: **Diagnostic Test/ Procedure**

In Case of thumb Impression: Identified by (Name)_____Age:_____
Sex:_____Relation
(if any):_____ Address &
ContactNo.:_____ _Signature of a person attesting thumb
impression: _____Date:_____

DECLARATION OF DOCTOR/ PERSON CONDUCTING PRE NATAL DIAGNOSTIC PROCEDURE/TEST

I,_____(name of the person conducting ultrasonography / image scanning) declares that the
while conducting ultrasonography /image scanning on Ms/Mr_____(name of the pregnant
woman or the person undergoing pre natal diagnostic procedure/test), I have neither detected nor disclosed the sex of her
foetus to anybody in any manner.

Date: _____ Signature:_____ ____

Name in Capitals, Registration Number with Seal of the Gynaecologist/Radiologist/Registered Medical Practitioner Conducting Diagnostic procedure

INSTITUTIONAL ETHICAL COMMITTEE,
STANLEY MEDICAL COLLEGE, CHENNAI-1

Title of the Work	:	Assessment of Normal Cerebral sulcal Development in foetus using MRI.
Principal Investigator	:	Dr. T Rajakumari
Designation	:	PG, MD (Radio Diagnosis)
Department	:	Department of Radio Diagnosis Government Stanley Medical College, Chennai-01

The request for an approval from the Institutional Ethical Committee (IEC) was considered on the IEC meeting held on 26.09.2016 at the Council Hall, Stanley Medical College, Chennai-1 at 2PM

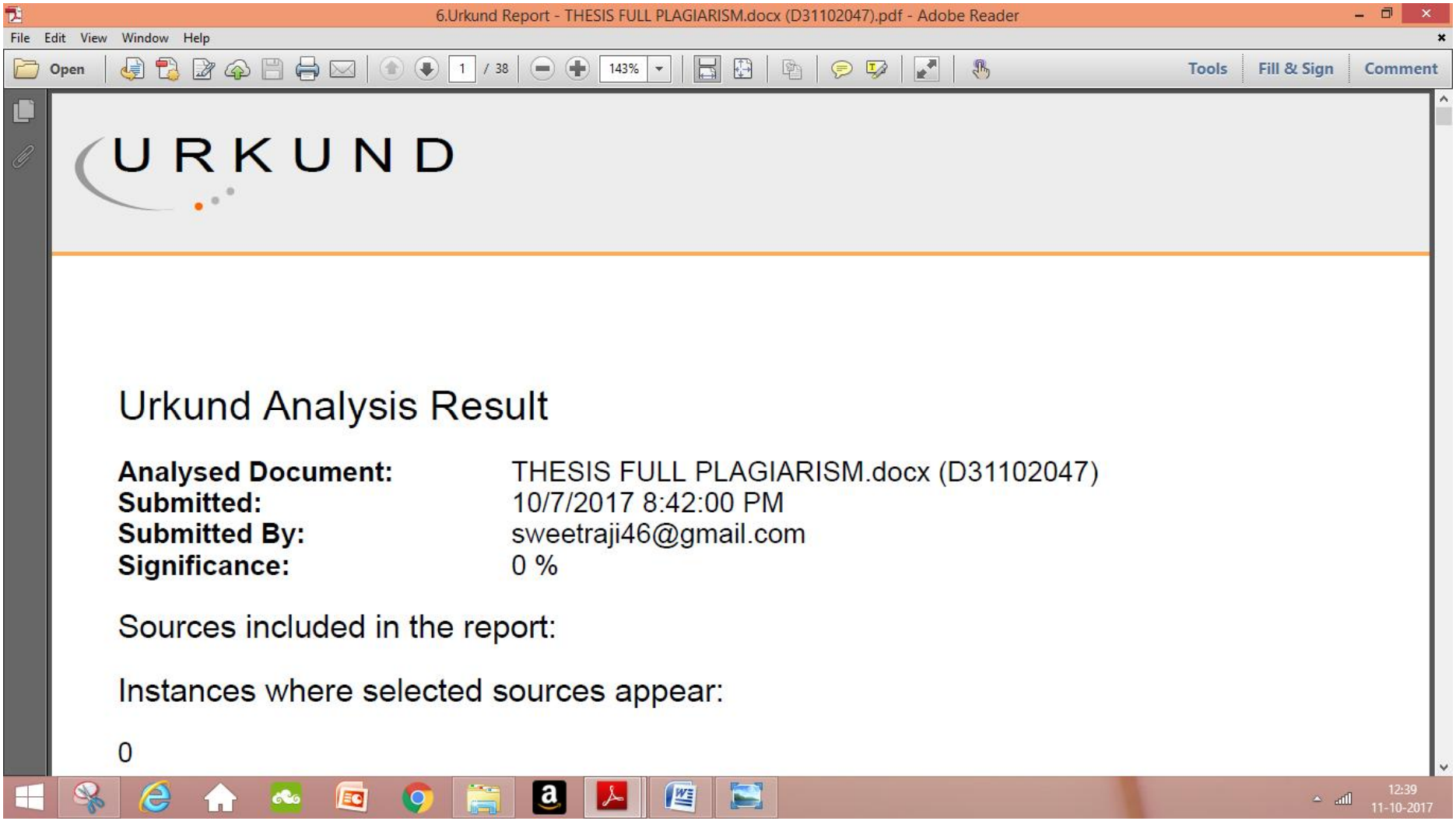
The members of the Committee, the secretary and the Chairman are pleased to approve the proposed work mentioned above, submitted by the principal investigator.

The Principal investigator and their team are directed to adhere to the guidelines given below:

1. You should inform the IEC in case of changes in study procedure, site investigator investigation or guide or any other changes.
2. You should not deviate from the area of the work for which you applied for ethical clearance.
3. You should inform the IEC immediately, in case of any adverse events or serious adverse reaction.
4. You should abide to the rules and regulation of the institution(s).
5. You should complete the work within the specified period and if any extension of time is required, you should apply for permission again and do the work.
6. You should submit the summary of the work to the ethical committee on completion of the work.

MEMBER SECRETARY, 7/11/16
IEC, SMC, CHENNAI

MEMBER SECRETARY
ETHICAL COMMITTEE,
STANLEY MEDICAL COLLEGE
CHENNAI-600 001.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CERTIFICATE – II

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